INSIDE: Pullout star charts

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October 2010

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Finding an earthlike planet with liquid water, such as in this artist's conception, would set the stage for some of the most exciting scientific discoveries of all time.

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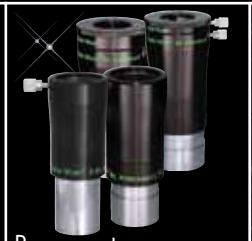
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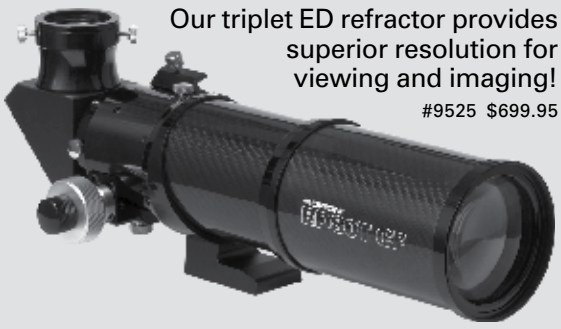

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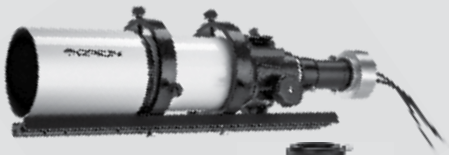

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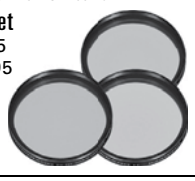

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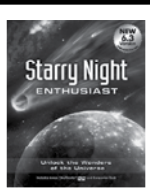

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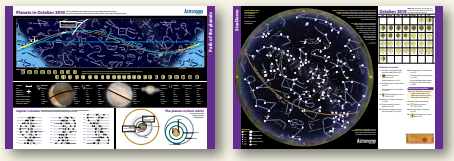


Path of the planets and StarDome.

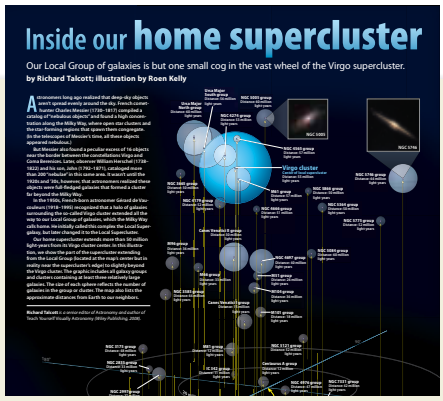
Astronomy
How astronomers will find another EARTH
All about the Double Cluster
How to pick a camera for astroimaging
10 top autumn binocular treats

Cover: Lynette Cook for *Astronomy*

ON THE COVER

Astronomers have long sought a haven among the cosmos, but before we can find another Earth, we must first understand what makes this one so special.

FEATURES


Inside our home supercluster
Our Local Group of galaxies is but one small cog in the vast wheel of the Virgo supercluster.
by Richard Talcott; illustration by Roen Kelly

28 COVER STORY
How astronomers will find another Earth
Finding an earthlike planet, the first step toward life in the universe, is closer than you might think. **DEBRA FISCHER**

34 **Illustrated: Inside our home supercluster**
Our Local Group of galaxies is but one small cog in the vast wheel of the Virgo supercluster. **RICHARD TALCOTT; ILLUSTRATION BY ROEN KELLY**

36 **The Sky this Month**
Jupiter shines big and bright. **MARTIN RATCLIFFE AND ALISTER LING**

44 **Explore the pulsar menagerie**
Astronomers are discovering many strange properties of compact stellar objects called pulsars. Here's how they fit together. **VICTORIA M. KASPI**

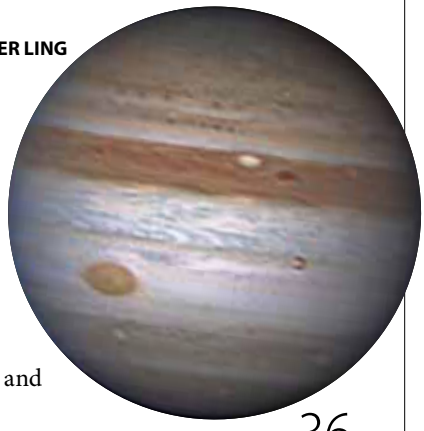
50 **Ask Astro**
Our Sun's finale.

52 **10 top autumn binocular treats**
All you need to enjoy these seasonal targets is a dark sky and good binoculars. **PHIL HARRINGTON**

54 **How to pick a camera for astroimaging**
Sky-shooting has never been easier. Stunning results may be just a click away with off-the-shelf digital SLRs. **MICHAEL A. COVINGTON**

58 **All about the Double Cluster**
Two brilliant open clusters in Perseus hold dozens of stars younger than the Sun. **RAYMOND SHUBINSKI**

62 **Astroimager's delight: Canon's EOS 5D Mark II**
Ease of use, tons of features, and a whopping 21 megapixels of resolution are all reasons to look at this camera. **MIKE REYNOLDS**



36

COLUMNS

14 **Strange Universe**
The limit of infinity.
BOB BERMAN

15 **Observing Basics**
Creating a community.
GLENN CHAPLE

16 **Secret Sky**
The Daughters of Dawn's Heart.
STEPHEN JAMES O'MEARA

18 **Evening Stars**
Pluto's second chance.
DAVID H. LEVY

68 **Imaging the Cosmos**
Signal-to-noise ratio.
TONY HALLAS

IN EVERY ISSUE

8 **This Month in *Astronomy***
Why search for other Earths?

10 **Astro Confidential**
Amy Barger, Jennifer Birriel, Neil Gehrels, Lisa Kaltenegger, Greg Laughlin.

12 **Letters**
A winning idea.

13 **Web Talk**

20 **Astro News**
Scientists recover asteroid-landing spacecraft.
Hubble views stellar nursery.
Water on the Red Planet.

64 **The Cosmic Grid**

65 **New Products**

65 **Advertiser Index**

69 **Deep-sky Showcase**

70 **Reader Gallery**

WEB EXTRA

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AT65EDQ image by Jason Blaschka.

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Why search for other Earths?

by David J. Eicher

Why do we care so much whether other planets like ours are out there in the cosmos? Are astronomers on the cusp of discovering other life-forms, intelligent ones perhaps? Or are we simply projecting another sense of our own importance into the galaxy and the whole cosmos? As astronomer Debra Fischer writes in this month's cover story, "A discovery of even simple extraterrestrial life will surely have deep ramifications for creatures on Earth, impacting our philosophies, religions, art, and science" (p. 28).

Fischer is well-qualified to describe the story of exoplanet searches. Besides being a professor of astronomy at Yale University, she is a member of the team led by Geoffrey Marcy at the University of California, Berkeley, that has uncovered many extrasolar planets. As of this writing, the total number of planets known outside the solar system is 464, and the number grows every month.

Spiral galaxy NGC 6946: How many Earths does it hold? Tony Hallas

Most of the planets found thus far are giants like Jupiter, too hot and inhospitable for life. In 2009, however, Gliese 581 d became the first potentially terrestrial planet found orbiting within the habitable zone of its star. It's a so-called super-Earth, with at least 7 times the mass of our planet, and it could hold an ocean of water. Moreover, it's only 20 light-years (that's 120 trillion miles) away.

Numerically, the odds for life and even for civilizations in the universe are pretty overwhelming. Something like 40,000 billion billion stars exist, each with the possibility of hosting planets. And certainly the confirmation of life on other worlds would prove a transforming moment in humankind.

But science is a brutally realistic and ambivalent mistress. Before getting too wired by some of the current TV shows that throw about dreams of interstellar travel (or time travel) like yesterday's news, realize the staggeringly immense scale of the universe. Photons travel quickly because they are massless. Anything with considerable mass, like a spacecraft holding people, would require an enormous amount of energy to make a journey long enough to reach even the closest stars. Logistical challenges would abound, to say the least. How would you store enough Twinkies in the ship's pantry for a 100,000-year-long trip?

Let's step back from lunging at the immediate sci-fi endgame for discovering another civilization — immediately, invariably, visiting it in person. Why not concentrate simply on the potential discovery of life of *any* type on another planet — something that would shake Earth's philosophical rafters for many years to come? That kind of discovery may not be too far off. And it doesn't require nearly as many Twinkies.

Yours truly,

David J. Eicher
Editor

Astronomy

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Dr. Edward M. Murphy is Associate Professor, General Faculty at the University of Virginia. Professor Murphy worked extensively on NASA's Far Ultraviolet Spectroscopic Explorer, which he continues to use in his research on the interstellar medium. Professor Murphy frequently lectures on astronomy to the general public.

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Astroconfidential

Go beyond the latest discovery, research, or theory and meet the professionals who make it all possible.

by Karri Ferron

Shihmei Barger, background: R. Williams (STScI)/Hubble Deep Field Team/NASA

Astroinfluences

Amy Barger

Professor at the University of Wisconsin-Madison and affiliate faculty at the University of Hawaii

How did you become interested in galaxy research?

From the time I wanted to be an astronomer, I knew I wanted to study distant galaxies. Beautiful nearby spiral galaxies first attracted me. But the idea that these magnificent structures had evolved from smaller, less orderly systems intrigued me even more.

My first opportunity to study galaxies came when I began my Ph.D. in 1993. My advisor suggested a thesis that depended on data from the repaired Hubble Space Telescope. We'd observe galaxy clusters at a range of distances corresponding to ages of the universe of around 9.5 to 11 billion years and classify the galaxies in each of the clusters according to their shapes. We'd compare the results across the clusters to look for signs of evolution and then infer which physical processes had been the most responsible for that change.

"Several times I have been fortunate enough to be in the right place at the right time to make discoveries with new instruments."

Since my thesis, I have focused on galaxies outside cluster environments. Several times I have been fortunate enough to be in the right place at the right time to make discoveries with new instruments. I made observations with the first camera that could image a piece of sky at submillimeter wavelengths with ample area coverage and sensitivity to detect distant, ultraluminous, dust-obscured galaxies. I also used the Chandra X-ray Observatory to resolve the uniform high-energy X-ray glow coming from the sky into newly discovered dust-obscured supermassive black holes.

OUR TURN

Neil Gehrels

Chief of the Astroparticle Physics Laboratory at NASA's Goddard Space Flight Center in Greenbelt, Maryland

What made you decide to focus your research on gamma-ray astronomy?

I was in graduate school doing a thesis on cosmic rays and heard some talks about the young field of gamma-ray astronomy. Here was a way to get at some cool physics, like the formation of elements in supernovae and gamma-ray bursts (GRBs). The more I heard about the field, the more excited I became. I was hooked!

What goals do you have for the missions you are working with?

Hah, there's a long list. I would love to detect a really nearby GRB in coincidence with a gravitational wave detection by a ground interferometer like the Laser Interferometer Gravitational-Wave Observatory (LIGO).

What are some of the most exciting things you've learned through your research?

For Supernova 1987A, we flew gamma-ray spectrometers on balloons and learned, along with other teams, that the inside of an exploding star is turbulent with mixing materials. With the Swift satellite, a big discovery was that the two classes of GRBs have entirely different mechanisms that cause them. It has been a great adventure.

Gehrels checks out the Swift satellite.

Neil Gehrels; NASA

What current studies in astronomy do you find fascinating?

Personally, I have always been fascinated with explosions like supernovae and GRBs. We live in a violent universe shaped by these amazing events.

Actually, there are many neat areas in astronomy besides just death and destruction. I love hearing about all types of recent discoveries, like the many new exoplanets. I bet it's a fun job covering all the news at *Astronomy* magazine.

What is the greatest challenge facing astronomy today?

A major scientific challenge is to learn what makes up the dark 96 percent of the universe. There are lots of theories, but scientists really have no idea what dark matter and dark energy are. A big concern for the next 10 years is how to afford the large high-tech observatories needed for progress — not just for dark matter and dark energy, but in all areas of astronomy.

A DAY IN THE LIFE OF ...

Tim Stephens (UCSC)

Greg **Laughlin**

Assistant professor of astronomy and astrophysics at the University of California, Santa Cruz

6:31 A.M. I'm still in pajamas, going through e-mail. I see that Paul Butler of the Carnegie Institution for Science has just finished reducing a new batch of radial velocities from the Lick-Carnegie Planet Search Team's recent Keck telescope run. I load this data into the Systemic Console, a website that publicly reports recent developments in the field of extrasolar planets (www.oklo.org), to see if our most interesting super-Earth candidates are holding up. For one candidate, the new velocity fails to match the prediction. Two of the other prospects, however, continue to look good.

7:17 A.M. Scramble through the morning domestic routine.

8:23 A.M. In my office at UCSC. Class starts at 9:30 A.M. Unplug the office phone. For the next hour, cram for my lecture. It's a class on numerical methods for graduate students, and the day's topic is N-body regularization.

10:50 A.M. Meetings with my students to discuss their research projects.

12:30 P.M. Lunch.

1 P.M. Research. I'm trying to understand how the upper atmospheres of eccentric short-period giant planets behave when they get blasted with intense irradiation during close approaches to their parent stars. I'm looking to see which transiting planets the Hubble Space Telescope can observe in order to watch the expected atmospheric escape unfold in real-time.

4:30 P.M. Write a blog post for oklo.org about the wildly eccentric planet HD 80606b's transit.

5 P.M. Hit "Publish," and the post is live. Back to the e-mail inbox.

GETTING TO KNOW

Jennifer Birriel

Jennifer **Birriel**

Associate professor of physics at Morehead State University in Kentucky

Best thing about working with students on a daily basis: They are full of enthusiasm and questions. It is a great pleasure to help them find answers to their inquiries and show them how science works as a process. Sometimes I get questions about topics I don't have an in-depth knowledge of. These queries remind me that one never stops learning, and I find myself doing a lot of research to give them an answer.

Greatest challenge facing astronomy education today: People often perceive astronomy as the science field with no practical application. As such, a great challenge facing educators is to make astronomy meaningful and relevant to students.

Best thing about writing an astronomy column: Writing for *Mercury* helps me keep up on astrophysics research and fulfills my passion for science writing. My writing and teaching create a synergy: Students' questions have inspired many of my columns.

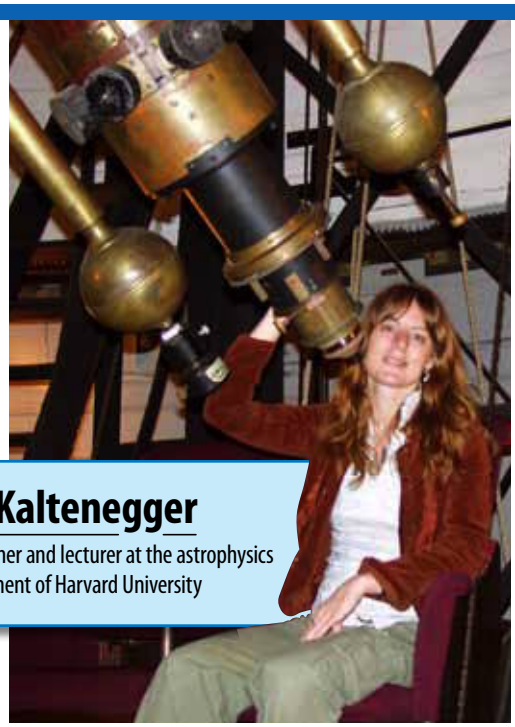
Basis for interest in light pollution studies: Years ago, my teenage alter ego lived in the suburbs of a major city and wrote about the evils of light pollution in a letter to the editor of the local paper. Back then, as an aspiring astronomer, I was only concerned about my future professional prospects. Now, as a parent, I am just as concerned about the negative economical and ecological impacts of light pollution.

Goals for the next 5 to 10 years: I plan to continue documenting local night sky brightness with the aim of reducing light pollution in my hometown. I also want to get students involved in archival research studies of variable stars because doing real science can be an inspiring experience!

Favorite things to do in your spare time: Spending time with my husband — who happens to be my best friend and a fellow physics colleague at Morehead State University — and our two children is one of my greatest joys. The four of us love hiking, biking, and camping.

Astro**fascinations**

What fascinates you most about exoplanet research?


Lisa Kaltenegger

Lisa **Kaltenegger**

Researcher and lecturer at the astrophysics department of Harvard University

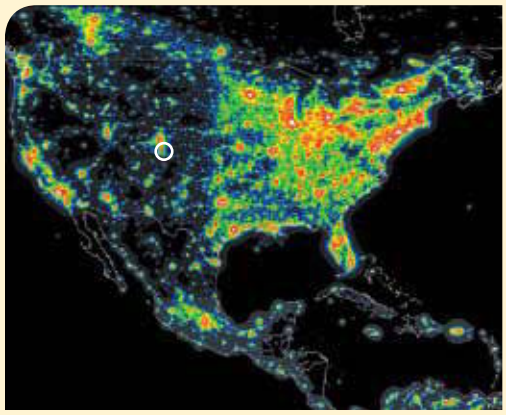
Unknown, amazingly different, and fascinating worlds are the breathtaking discoveries we are now making on a day-to-day basis using telescopes in space and on the ground. Trying to figure out what is happening on these worlds is what I do. It's like solving a fascinating puzzle: how such worlds could work and how I could decipher their fingerprint of light — what we collect with our best telescopes. But what does each fingerprint mean?

We already found varied worlds, from huge gas balls bigger than Jupiter to small planets that just might be rocky like our own. Some are so close to their star that they bake in its heat. They are so incredibly hot that the atmosphere evaporates, and there could be permanent lava oceans on their surfaces. Other worlds are so cold that even parts of their atmosphere freeze out.

So many new worlds exist out there in the sky that we are just starting to discover. We are a little like the great explorers of old. When looking up at the sky at night, just think about how many of these stars have hot giant planets orbiting them in only a few Earth days. Imagine that one of those sparkling dots of lights has a world like ours orbiting it — and we might discover it in the next few years.

A winning idea

Due to budget cuts and a failed tax proposal, the city of Colorado Springs, Colorado, recently decided to turn off one-third of the city's streetlights to save an estimated $1.2 million for 2010. This has lessened the light dome hovering over the city and has also allowed me in nearby Manitou Springs to squeeze a few more magnitudes of deep-sky objects out of my 10-inch Dobsonian. Budget savings, less light pollution, and more faint fuzzies — there is no downside to this! — **Joshua D. Warren,** Manitou Springs, Colorado



Although much of the United States teems with light pollution, some cities have taken measures to decrease it, even if by accident. Colorado Springs, Colorado, (circled) turns off about one-third of its lights at night to save money. Istituto di Scienza e Technologia Dell'inquinamento Luminoso

Continuing IYA

David H. Levy's April 2010 column, "A permanent IYA," inspired this letter. For years, I had casually wanted a telescope, but the deterring factor (aside from procrastination) was the perceived high cost.

Celestron marketed the FirstScope as an International Year of Astronomy (IYA) "starter instrument." Reading the ads lit the lightbulb over my head: "A telescope for $50?" Of course, that suckered me onto astronomy websites, and I now have a telescope. My rationalization is that it's a retirement present to myself.

This scope is entry level, but my "astro-purpose" is to enjoy "oh wow" moments, and it does just that. When you hear "oh wow" from your kids, you feel like you've done something right.

I appreciate *Astronomy* magazine because even your experienced contributors still seem to enjoy "oh wow" moments and want to pass them on. Thank you. The enjoyment has and will continue well past 2009's IYA. — **Bill Harper,** Astoria, Oregon

Our abnormal star

Thanks so much for the June 2010 article on the Sun, "Is the Sun an oddball star?" For years, I felt irritated whenever I heard a scientist state that the Sun is average. "Accepted wisdom" that our star is ordinary stems from the fact that it is in the middle of its life and falls in the middle of the Hertzsprung-Russell diagram. Middle doesn't make it average, as about 5 percent of stars, from what I read, are like our Sun.

Before reading the June article, I had just put on my to-do list a reminder to message Bob Berman and ask him to please write about this wrong idea. Thank you for allowing me to cross something off my list. — **Laura Graham,** Powhatan, Virginia

Explore other worlds

When reading a copy of your December 2009 issue, I was struck by the negative attitude toward human exploration of the solar system expressed in the Letters section. What has happened to the American pioneering spirit? While it is wonderful to see the data that probes and rovers send back to Earth, the goal should be to plant self-sustaining colonies that can explore these worlds thoroughly and create vibrant new outposts of humanity. I add that our burgeoning population on Earth may desperately need the resources that could be available. — **Malcolm Cleaveland,** Fayetteville, Arkansas

The underdog

I read Dan Falk's April 2010 article, "Who was Thomas Harriot?" with great pleasure. I was astonished at how little I knew about Harriot and how much he had done — especially within his book *Artis analyticae praxis*. Publishing is a necessity for scientists — both nowadays and centuries ago. I appreciated this article, and I look forward to others that focus on great people who aren't as well-known as they deserve. — **Thomas Hofstätter,** Vienna, Austria

Just the facts

I have been an avid amateur astronomer since 1972 and a subscriber to your magazine for almost as long. I want to thank you for the January 2010 "Star of Bethlehem" story. Having been somewhat agnostic about the whole Christmas star affair, I found the article very interesting from a scientific and astronomical point of view. I want to express my appreciation to your magazine for putting forth this type of information and then allowing us, the readers, to form our own opinion.

Also, please allow me to express my constant delight in the articles by Bob Berman. I always look forward to reading his work first. — **Pete Allison,** Oxford, Mississippi

Corrections

The Eta Carinae Nebula caption on the Milky Way Mosaic (May 2010) relates to the massive star Eta Carinae and its gas and dust lobes. The image that accompanies the caption shows the central 50 light-years of the 300 light-year-wide Carina Nebula, of which Eta Carinae is a small part (at the image's left).

In the June 2010 Reader Gallery, credit for the image of Sharpless 2–240 should have gone to Neil McMickle. — ***Astronomy* Editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Webtalk

Autumn observing targets for small telescopes

In this video, *Astronomy* magazine Senior Editor Michael E. Bakich highlights the objects you can see this fall using a small telescope. Targets include the Andromeda Galaxy, the Helix Nebula, globular cluster M2, the Blue Snowball, and more.

MULTIMEDIA

Featured video: Sketching from the telescope A+

Astronomy Editor David J. Eicher sketches elliptical galaxy NGC 1023 and shares his techniques for putting on paper what he sees in the eyepiece.

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by Bob Berman

The limit of infinity

The idea of an endless universe can make anyone uncomfortable.

Does infinity make you edgy? Uncomfortable? You're not alone. Welcome to the Infinity Counseling Support Group. Warning: These sessions can produce dizziness.

It all began with my August 2009 column, which showed how to make sense of distant galaxies in an expanding universe. I said that we can only observe 1.6 percent of the universe at best because the light from 98.4 percent of all galaxies will never reach us. It's even more likely the universe is infinite, in which case all we ever will observe is 0 percent.

This brought a flood of mail. How can the universe be infinite? What does that mean? And how do we know?

The evidence is the Hubble constant, the baryon acoustic oscillations, the cosmic microwave background anisotropy angular power spectrum, and the supernova flux versus redshift. Supporting data include the flat topology of space, the deuterium abundance, and the ratio of dark matter to baryonic matter. Has the room started to spin?

Writing me in April, cosmologist Ned Wright of UCLA added, "The simplest models are infinite in space and finite in time. So of course [galaxies] expand faster than light. The universe is expanding faster than light now, including distant galaxies that we presently see."

Questions arise. How can infinite space form in a limited time? Is there infinite material in this infinite space? Never-ending stars?

I asked my friend Tarun Biswas, a relativity professor at the State University of New York at New Paltz. His answer: "General relativistic models, based on Friedmannian topology, portray space as a sphere with a three-dimensional surface, and time runs 'perpendicular' to it. So, space can be finite or infinite depending on the sphere's radius. However, time is infinite."

Aha, so time is *not* finite. Is it possible that Wright was wrong?

Biswas continued: "All cosmological models are based on a uniform density of matter. Hence, infinite space means infinite total mass."

Galaxies without end? This is a big change from when I went to college. Then, the cosmos was supposedly "finite but unbounded," meaning it has a limited quantity of matter, with curved space so you'd never reach a wall.

Let's stay with Biswas: "Now that I've stated the popular wisdom, I feel an uncontrollable urge to give some personal opinions. Several of the accepted 'facts' are strongly model dependent. For example, we assume space to have a uniform mass density not because we know it to be so but because it is the easiest assumption in the absence of information. At the scale of the universe, the distance up to which we have real data is negligibly small — particularly if the universe is infinite! How can we know that 98.4 percent of the universe is invisible to us if we have never seen it?"

Who can honestly grasp these various infinities of matter, density, space, and time?

Time-wise, evidence points to a Big Bang even though it's problematical. It proclaims a birth moment when many measurable quantities were exactly infinite (infinity again!), but this, alas, has no physical meaning. (Now I'm *really* dizzy.)

The Big Bang scenario says time started at a finite point 13.7 billion years ago and extends future-ward to infinity. Except the WMAP spacecraft merely gives the elapsed time since the last scattering of the cosmic microwave background (CMB). That omnipresent glow supposedly originated 380,000 years after the Big Bang, when the universe became transparent. But, says Biswas, "How much time passed *before* the CMB is experimentally unknown. It could be infinite. The standard wisdom is that negligible time elapsed. But this is a conjecture based on grand unified theories that have no experimental basis so far."

I used to love this stuff. Now, as it's become more likely that the universe is actually infinite, I'm starting to hate it. There are too many unknowns. Each hallway ends in a blur. There's no endpoint. And who can honestly grasp these various infinities of matter, density, space, and time? Worse is when "experts" jabber as if they had a clue. They disingenuously exude confidence, but they *know* they're in over their heads.

Some things about space naturally silence us, like that Walt Whitman poem about leaving a tedious astronomy lecture to step out under the beautiful stars. I'm starting to wonder if some secret scripture somewhere says, "You can discover how the Sun shines and what lies beneath the red martian sands. But the nature of the entire universe, this you may not know."

Today's cosmology seems a masochistic arena where the unsolvable meets the inconceivable. The appeal is gone. Too many other cool astronomy things are happening. So go on ahead. Don't wait for me. When this scientific train reached the station named "infinity," that's when I got off.

Browse the "Strange Universe" archive at www.Astronomy.com/Berman.

Contact me about my strange universe by visiting **http://skymanbob.com**.

by Glenn Chaple

Creating a community

Reaching out to other astronomy enthusiasts has become easier than ever.

The other night, I dropped in on my astronomy club, the Amateur Telescope Makers of Boston. From there, I traveled 30 miles southward to the Amateur Astronomical Society of Rhode Island (the Skyscrapers) and then trekked to the West Coast to visit the Los Angeles Astronomical Society. How was I able to conduct this cross-country tour in a single evening?

I'm not a wealthy jetsetter, nor can I fly at super speed through the air like Superman. In fact, I didn't appear at any of these clubs in person. Instead, I used the Internet to visit their websites.

Through the power of the web, astronomy outreach and community creation has become easier than ever. Connecting with others who share our passion is as simple as a few clicks of the mouse.

In addition to running websites, these astronomy clubs have another outreach tool in common. Each puts out a monthly newsletter that provides information about the club, its members, and activities. It may include astronomy-related news items, a monthly sky calendar, and descriptions of currently observable sky objects.

An astronomy club newsletter is an important vehicle of communication, not only to members but also to the local community. It provides astronomy outreach while generating positive publicity for the organization.

You too can harness the power of the web. Refer to www.Astronomy.com for a list of astronomy clubs in the United States. Scroll down to "Groups" under the heading "Community" on our home page. If your club doesn't appear on the list or the information is out of date, make sure to have it included or updated by filling out a submission form listed on the left side of the page.

Browse the "Observing Basics" archive at www.Astronomy.com/Chaple.

Not in an astronomy club but still want to reach out to individuals and share your interests and insights? Blogging is a great way to form an astronomy network.

Take the blogger at http://niteskygirl.blogspot.com. NiteSkyGirl (she prefers to keep her actual name under wraps) is somewhat of an astronomical rarity — a full-time researcher who actually enjoys and promotes backyard astronomy. Currently working on a master's degree at George Mason University, she is a member of the McDonald Observatory Skywatch Team and a solar observer for the Science Environment Center.

Herman Heyn, "Baltimore's Street Corner Astronomer," has been bringing the night skies to the masses for more than 20 years. Sidewalk astronomy remains a key way to encourage interest in the hobby. Todd Baker

But it's through her blog that NiteSkyGirl has made her greatest astronomical contribution. Punctuated by her infectious enthusiasm, the blog blends a personal diary of her telescopic adventures with astronomy news and helpful hints for backyard astronomers. NiteSkyGirl currently boasts a following of more than 1,300 registered readers, including a cadre known as the "NiteSkyGirl Krew." It's a fun site to visit, especially if you're suffering from the "astronomy blahs" and need a boost of inspiration.

Astronomy newsletters and blogs like NiteSkyGirl are modes of outreach that cater to individuals already interested in astronomy. But what about that segment of the populace that hasn't been exposed to the wonder of the night sky? That can take a little more footwork, so this is where the sidewalk astronomer comes in. Personified by John Dobson of the San Francisco Sidewalk Astronomers (and the inventor of the Dobsonian mount), a sidewalk astronomer is an individual who sets up a telescope in a public place, aims it at a showpiece sky object like the Moon or a bright planet, and invites passersby to take a look.

If you happen to be strolling along Baltimore's Inner Harbor on a clear evening, you're likely to stumble upon a sprightly 79-year-old gentleman standing beside a telescope, its gray-blue tube decked with a sign that reads, "Baltimore's Street Corner Astronomer HAV-A-LOOK!" For more than 20 years, Herman Heyn has brought the night sky to tens of thousands of visitors, from kindergarten-aged youngsters to senior citizens. He has even hosted astronomical royalty. One of his guests was noted Space Science Institute planetary scientist Heidi Hammel. There's more to Heyn's sidewalk astronomy than a mere glance through his telescope. He also distributes astronomy-related handouts and sticky notes with messages like, "I saw Jupiter from Harborplace."

The astronomical community owes a debt of gratitude to sidewalk astronomers like John Dobson and Herman Heyn. Their efforts have produced a corps of amateur astronomers who otherwise might have never become involved in the hobby. And with the Internet connecting us like never before, we can reach out to those who've been infected by the astronomy bug and create a true global community of astronomy enthusiasts.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com.

by Stephen James O'Meara

The Daughters of Dawn's Heart

It may be tricky, but you too can spot Jupiter's largest moons with your naked eyes.

Four centuries ago, Galileo Galilei turned his tiny telescope to Jupiter and discovered its four largest moons. The satellites later received Roman names, as well as numerals reflecting the order of their distance from Jupiter: Io (I), Europa (II), Ganymede (III), and Callisto (IV). Were it not for their close proximity to brilliant Jupiter, all four would be viable naked-eye targets. Nevertheless, several well-documented historical accounts exist of sightings of at least one (and sometimes more) of these moons.

Because Jupiter reached opposition on the evening of September 27, 2010, now is a great time to test the resolving power of *your* unaided eyes by looking for these "clinging" moons.

Before I reveal the bugaboo of this challenge, I thought you might enjoy a few fascinating accounts of possible naked-eye detections, including those by the |Xam-speaking San tribe of South Africa (probable descendants of the original human inhabitants of sub-Saharan Africa), as told in their legend of Dawn's Heart Star.

Dawn's child

Willie P. Koorts of the South African Astronomical Observatory discussed various interpretations of Dawn's legend in the July 2007 issue of *African Skies*. In one simplified version, Dawn's earthly incarnation was murdered and skinned, but his sparkling heart flew into the sky where it became the Morning Star (in this case, Jupiter). There, Dawn had a mysterious relationship with his daughter (Dawn's Heart child or star).

As Dorothea F. Bleek (1873–1948) explains in *A Bushman Dictionary* (published posthumously in 1956), Dawn "swallows her … and, when she is grown up, he spits her out again." His daughter, in return, gives birth to another child, and they follow him in the sky. Koorts believes it's plausible that Dawn's Heart child (and grandchild) represents one (or two) of Jupiter's moons.

Koorts' paper also offers arguments that the two heavenly bodies must have always been close together; otherwise, how could they have inspired such an intimate relationship? Additionally, the observed actions must have repeated themselves to have made such a lasting impression. If true, Koorts says, the |Xam-speaking tribes must have had "above-average eyesight, or they, knowingly or unknowingly, developed a technique to enable them to see this."

A legendary tale

More-modern naked-eye sightings of Jupiter's moons are also the stuff of legend. One of the best documented occurred on the night of April 3, 1874, when the renowned 19th-century British observer William F. Denning "cut off the planet's marginal rays" and "unmistakably saw" Ganymede and Callisto near their greatest western elongations. He reportedly spied them "steadily and separately several times."

Denning confirmed his observations with his telescope's 5x finder and a 3x opera glass. Of the naked-eye view, Denning wrote, "And from the remarkable ease with which they were visible, I was not surprised that unaided vision sufficed to reveal them, though previously I had been sceptical on the point, knowing it to be a disputed, albeit a well-attested one."

Mentall's child

One of my favorite tales comes from a friend, E. Talmadge Mentall, who loves to

E. Talmadge Mentall

One memorable night about 40 years ago, E. Talmadge Mentall and his daughter Valerie A. Belcher (now grown up) spied the Galilean moons through a telescope and by naked eye, respectively.

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.

NASA

share this experience from the early 1970s when he was living in Dorchester, Massachusetts: "When my daughter Valerie was about 8 years old, with her help, I put together a 3-inch Newtonian telescope. When it was finished, we took it out to the back porch and I trained it on Jupiter. It so happened that all of the Galilean satellites were lined up on one side of the planet. I explained to Valerie what she was about to see: 'Jupiter is the brightest object, and the moons go up from Jupiter.' But Valerie said, 'No Daddy, the moons go down from Jupiter.' "

When Mentall took his eye away from the eyepiece and looked at his daughter, he saw her standing next to him gazing up into the sky. He then asked her if she could see the moons with her naked eyes. "Yes, Daddy," she replied. "They're real tiny right next to Jupiter." Whereas Mentall gazed at the moons through an inverting telescope, his daughter could see them right-side up.

A more recent success story

Southern Arizona amateur astronomer Ray Brooks made several naked-eye detections of both Ganymede and Callisto in 2007.

His first success came on the morning of June 14, when Ganymede was about 280" from Jupiter. "A 7mm pupil diameter would require an occulting bar at least 16.7 feet [5.1 meters] away from one's eye to ensure that stray light from Jupiter would not interfere with perception," Brooks explains. So he positioned himself 53 feet (16m) away from a "perfectly angled ziggurat" on the roof of his Santa Fe-style garage, which lay perpendicular to the orbital plane of the Galilean moons.

Brooks notes that Jupiter took 3 seconds to pass the occulting edge and "blink out." Then he saw Ganymede, which blinked out almost 19 seconds later. Brooks repeated the experiment successfully several times simply by moving the concrete block on which he was sitting farther back. During each attempt, he says, Ganymede "would be very apparent for about 9 to 11 seconds," never again the full 19 seconds.

On June 25, Brooks spied both Ganymede and Callisto the same way. "Callisto was certainly not as dramatic as Ganymede," he says, "but it definitely lasts longer, taking almost twice the time to reach the occulting edge of the garage." That night, he repeatedly sighted the two moons 15 times!

The bugaboo

As we've seen, all four moons are bright enough to be visible to unaided eyes: At mean opposition, Io shines at magnitude 4.8, Europa at 5.2, Ganymede at 4.5, and Callisto at 5.5. The problem is the maximum apparent distance of each moon from Jupiter: Io, 2.3'; Europa, 3.7'; Ganymede, 5.9'; and Callisto, 10.3'.

Considering that one of the most stringent tests of visual acuity is the ability to split Epsilon (ε) Lyrae — a pair of stars (magnitudes 3.5 and 3.9) separated by 3.5' — you can understand the difficulty of visually pulling these moons, especially Io and Europa, out from Jupiter's intense glare, which can overpower the eye in a dark sky. Any aberrations in the eye also complicate the task by creating spikes and flares that can further inhibit the view.

Stephen James O'Meara

Jupiter's Galilean moons appear here as an observer might see them with the unaided eye under perfect seeing conditions (from left to right: Callisto, Ganymede, Io, Jupiter, and Europa). Note how the planet's glare (and flares and spikes from eye aberrations) can affect the visibility of the innermost moons.

Interestingly, in a 1991 *Publications of the Astronomical Society of the Pacific* paper titled "Glare and Celestial Visibility," Brad Schaefer (now at Louisiana State University) argues that while "normal observers cannot hope to see the Galilean satellites under even the best of conditions … keen-eyed observers should be able to spot all four moons at elongation under optimal conditions."

How many can you see? Be sure to let me know at someara@interpac.net.

Ray Brooks of Arizona took advantage of a "perfectly angled ziggurat" to block Jupiter's bright light, allowing him to discern Ganymede and Callisto numerous times in 2007. Raymond Brooks

by David H. Levy

Pluto's second chance

The planetary scientists of tomorrow choose a definition of planet *for today.*

In 2006, the International Astronomical Union (IAU) voted to demote Pluto to dwarf planet status. Four years later, Pluto reclaimed its status as the ninth planet after a second vote — at least, it did so in the eyes of the unofficial voters.

Although the new vote did not involve members of the professional astronomical community, I say it is just as valid. In my discussions with these second voters about Pluto, I emphasized that my opinion to keep it a major planet had nothing to do with science, despite the scientific reasons that it orbits the Sun and its gravity molded the object into a sphere. In fact, 4 years ago an IAU-appointed committee — headed by the great Harvard astronomer Owen Gingerich and including such notables as Massachusetts Institute of Technology astronomer Rick Binzel and science writer Dava Sobel — cited these same reasons. They unanimously recommended that Pluto, its moon Charon, the asteroid Ceres, and the Kuiper Belt object Eris all be considered major planets.

I agree with the committee and believe they did a superb job. But the full IAU membership ignored their work and voted to demote Pluto, defining "planet" as an object in orbit around the Sun that gravity has transformed into a sphere *that has also* cleared out its orbit of smaller bodies.

My opinion on the subject stems from my longtime close friendship with Pluto discoverer Clyde Tombaugh (1906–1997). He certainly saw this coming; in his final years, he fretted about the IAU eventually robbing him of his signature discovery.

Some elected officials have already listened to the protests of Plutophiles like me and made changes. The legislatures of Illinois and New Mexico, where Tombaugh was born and where he lived the last 50 years of his life, passed clearly worded resolutions insisting that when elusive Pluto is visible in the skies over these states, it is legally a major planet. Moreover, if you plan to build a home in New Mexico's Pluto Park area, at Rancho Hidalgo, where Tombaugh's 16-inch telescope still points skyward, you must sign a contract supporting Pluto's status as a major planet. I applaud these decisions.

After all, what of the future, when hundreds or thousands of Pluto-sized worlds might turn out to hide in the Kuiper Belt? Are they all demoted to dwarf planet status as well? If you define "planet" simply by using only the characteristics of the world itself (and not the characteristics of its orbit), then the IAU is just plain wrong.

About 4 years after their vote, I thought it was high time to bring it up again and chose the most fitting place I could think of — an elementary school named Roslyn in Westmount, Quebec. The school is special to me because I spent 5 years there beginning in 1956. It is the forum that saw my first lecture in the spring of 1960. Roslyn has something else going for it right now: Roger Pelland, an experienced and truly exceptional science teacher. Because the definition astronomers select today will affect the scientists of tomorrow, why not let children have a role in the decision? After all, it is they who will have to live with the eventual definition of "planet."

Roslyn's campus is not only home to the author's grade school classrooms, but it was also where the recent Pluto vote took place, unofficially reinstating it as a major planet. David H. Levy

The third graders voted unanimously to reinstate Pluto's planetary status, and the fifth graders voted for it 56 to 6, for a total vote of 100 to 6. The results are consistent with those already taken among millions of school children across the world.

I suspect that like many good words, "planet" will one day have several definitions, from which anyone can choose the one most palatable. In the meantime, I believe the children of the world, represented by some very clever young minds from Canada, have spoken clearly. They do not want the politics of a distant organization to dictate rules about the natural world they will enjoy and of which they will someday be in charge. Good work, Roslyn, and *vive Pluto*!

Browse the "Evening Stars" archive at www.Astronomy.com/Levy.

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Foreign comets A paper in the June 10 issue of *Science Express* argues that many well-known comets — such as Halley and Hale-Bopp — originated in other solar systems.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews

Merger party. This still from a recent simulation shows many small satellite galaxies colliding to form a larger Milky Way-like galaxy about 5 billion years ago. Andrew Cooper, John Helly (Durham University)

Simulation shows old stars are outsiders

A new computer simulation supports the idea that many of the Milky Way's oldest stars are remnants from captured smaller galaxies, instead of being born inside our galaxy. These findings align with predictions by most cosmologists. The study will appear in an upcoming issue of the *Monthly Notices of the Royal Astronomical Society.*

Andrew Cooper, of Durham University in the United Kingdom, and his colleagues simulated the evolution of stars and dark matter (the cosmic glue that holds the universe together) according to the universal laws of physics. The simulation showed the progression of structure from about 13 billion years ago until the present.

While the Milky Way's disk harbors young stars, including our Sun, the galaxy's surrounding stellar halo contains ancient stars, about 10 billion years old. "Like ancient rock strata that reveal the history of Earth, the stellar halo preserves a record of a dramatic primeval period in the life of the Milky Way which ended long before the Sun was born," explains Cooper. The astronomers found that the halo contains stellar debris left over after a period that ended about 5 billion years ago when many small galaxies collided and ripped each other apart. — **LIZ KRUESI**

22 Water on the Red Planet

22 Findings allow for possible life on Titan

24 Kuiper Belt object details resolved

24 Exoplanet seen moving

26 Astronomers directly measure exoplanet mass for first time

Lunar oasis. The ever-familiar Moon surprised astronomers once again with recent findings that much more water lurks within rocks on Earth's satellite than previously thought. NASA

Lunar water estimates increase

The Moon has once again proven itself a fertile ground for scientific research. A June 14 paper published in the Online Early Edition of the *Proceedings of the National Academy of Sciences* estimates the volume of water molecules trapped inside lunar rocks could be much greater than previously estimated, perhaps greater than the amount in Earth's Great Lakes.

Scientists at NASA, which provided the research funding, are quick to point out this doesn't mean giant seas of water exist on the Moon. "In this case, when we talk about water on the Moon, we mean water in the structural form hydroxyl," says Jim Green, director of the Planetary Science Division at NASA Headquarters in Washington, D.C. "This is a very minor component of the rocks that make up the lunar interior."

Still, the finding has significant implications for lunar history. The amount and type of water found mean it has likely been present in some form since the Moon's formation. — **BILL ANDREWS**

Long asteroid journey. **The Japan Aerospace Exploration Agency's asteroid-trotting Hayabusa spacecraft re-entered Earth's atmosphere June 13 over Australia.** NASA Ames Research Center/Jesse Carpenter/Greg Merkes

Scientists recover asteroid-landing capsule

After its long journey to an asteroid and back, Japan's Hayabusa spacecraft's return capsule landed safely in Australia June 13. It was the first mission designed to bring back a sample from an asteroid's surface, though due to a technical glitch it's still uncertain whether it actually succeeded.

The Japan Aerospace Exploration Agency heads the mission, which launched in 2003 and arrived at 25143 Itokawa, a small near-Earth asteroid, in 2005. It was then supposed to fire projectiles into the asteroid's surface to kick up dust for the collection container, but scientists don't know if they actually fired. Still, they remain hopeful.

"There may be a chance that during the touchdown, it might have kicked up some material that made its way into the sample container," says Paul Abell, a research scientist at the Planetary Science Institute and member of the Hayabusa team. "The chances are slim that we got any samples, but you never know." The spacecraft search team recovered it June 14, and Japanese scientists have found some dust in the container, but it will take months to determine if it's genuine asteroid material or just earthly contamination.

Even if it didn't collect any space dust, the mission was successful in several of its other science goals. "Hayabusa has really changed the way we think about these asteroids," says Abell. "When we got there with our spacecraft, we were actually very surprised." — **B. A.**

NASA/ESA/Jesús Maíz Apellániz (Instituto de Astrofísica de Andalucía, Spain)

Hubble views stellar nursery

Baby carriage. **On June 22, astronomers released this Hubble Space Telescope image of the second-largest star-forming region in our galactic neighbor, the Large Magellanic Cloud. The region, LHA 120-N 11 (also known as N11), extends more than 1,000 light-years across. Three successive generations of stars created the shells of gas and dust in the nebula. Each grouping formed farther from the nebula's center than the previous one. The star cluster in the image's lower right quarter is NGC 1761. — L. K.**

QUICK TAKES

A HANDLE ON HANNY'S

The Netherlands Institute for Radio Astronomy announced new observations June 24 of Hanny's Voorwerp (the unexplained gas cloud near galaxy IC 2497) that support predictions of intense galactic energy sources.

GALACTIC COLLISIONS

Galaxy crashes cause the massive black holes at the centers of most galaxies to "switch on," after which they become much brighter, according to a June 20 paper in *The Astrophysical Journal Letters*.

PARTICLE COLLISIONS

Fermilab scientists announced an unexpected difference in the masses of neutrinos and antineutrinos June 14 at the Neutrino 2010 conference in Athens, Greece.

BLAZING DAWN

NASA's ion-propelled Dawn spacecraft beat an accumulated acceleration record in space June 5, topping 2.7 miles per second (4.3 km/s), the space agency announced June 7.

A STAR IS BORN

A June 1 paper in *The Astrophysical Journal* describes what might be the youngest star ever observed — a protostar just beginning to form in the Perseus region of the Milky Way.

OVER DOUBLE HUBBLE

The Large Binocular Telescope in Arizona, already the world's biggest optical scope, has received an adaptive optics upgrade, making its images more than 3 times sharper than Hubble's.

EXOPLANET EXEGESIS

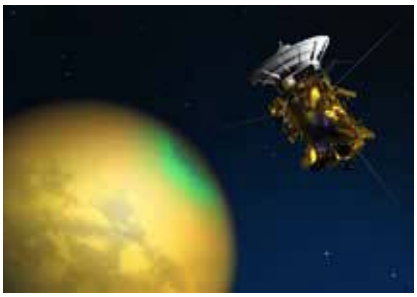
On June 15, NASA's Kepler mission released 43 days' worth of science data on more than 156,000 occasionally dimming stars so astronomers can determine if exoplanets are the cause.

KAVLI CONQUERORS

The Kavli Foundation announced its 2010 astrophysics winners June 3: Jerry Nelson of the University of California, Santa Cruz; Ray Wilson, formerly of the European Southern Observatory; and Roger Angel of the University of Arizona, Tucson.

SKY SEARCHER

Astronomers announced June 16 that the first Pan-STARRS telescope is fully operational and ready to begin scanning the skies for asteroids and other objects.



Lifelike data? **NASA's Cassini orbiter, depicted here during a flyby of Titan, has provided data consistent with the presence of theoretical methane-based life on the surface of the saturnian moon.** NASA/JPL

Findings allow for possible life on Titan

Two papers analyzing chemical activity from NASA's Cassini observations of Saturn's moon Titan have strengthened the case for the existence of life on the moon's surface. Although they don't constitute proof — or even evidence — of life, the data are consistent with theoretical predictions of how life on the exotic world might affect its surroundings.

The first paper, available online and in the August *Icarus*, describes a flow of hydrogen molecules through the atmosphere that vanish at the surface. "It's as if you have a hose and you're squirting hydrogen onto the ground, but it's disappearing," says author Darrell Strobel of Johns Hopkins University. Astrobiologist Chris McKay of NASA's Ames Research Center says hydrogen is the "obvious gas for life to consume on Titan."

The second paper, available online and in a future issue of *The Journal of Geophysical Research*, reports a lack of acetylene and an abundance of organic compounds on the surface of Titan. "All that implies Titan is a dynamic place where organic chemistry is happening now," says lead author Roger Clark of the United States Geological Survey.

It's important to remember, though, that chemical processes are more likely than life to explain these findings. "Scientific conservatism suggests that a biological explanation should be the last choice after all non-biological explanations are addressed," says Mark Allen of NASA's Jet Propulsion Laboratory, before suggesting several such explanations.

In the meantime, Cassini will continue observing and providing new data. **— B. A.**

Water on the Red Planet

A slew of Mars research appeared in June's scientific journals. Each of the papers provides evidence for the presence of water on larger areas of the Red Planet.

Scientists reanalyzed a rock outcrop that NASA's Spirit Mars Rover originally examined in 2005. They found high concentrations of carbonate, a mineral that originates in wet conditions but dissolves in acid. Therefore, the ancient water on Mars could not be acidic, which makes it favorable for life.

"Small amounts of carbonate minerals have been detected on Mars before," says Steve Ruff of Arizona State University. But this time astronomers see rock outcrops that "are about 25 percent carbonate by weight, by far the highest abundance we've seen on Mars." The team's findings appeared in the June 4 *Science*.

Other recent studies focused on widespread water on Mars. One group argues that an ocean covered one-third of the martian surface some 3.5 billion years ago. Gaetano Di Achille and Brian Hynek, both of the University of Colorado at Boulder, combined data from multiple orbiting Mars missions to investigate the planet's deltas, river valleys, and topography. Specifically, they studied 52 martian deltas and roughly 40,000 river valleys.

They found that more than half of the deltas and river valleys likely marked the boundaries of an ancient ocean. These geologic features are all at a similar elevation, implying that they were connected to the martian ocean or to large adjacent lakes. The amount of water in this vast ocean would have totaled about 30 million cubic miles (125 million cubic kilometers). That's about

ESA (C. Carreau)

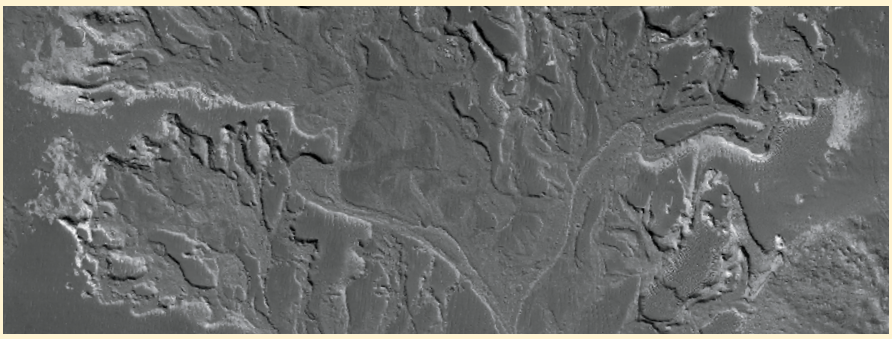
Red and wet. **Recent studies have found that Mars likely had water not just in the southern regions, but in the northern lowlands as well.**

10 times less than the current volume of Earth's oceans. The study was published June 13 online in *Nature Geoscience*.

Another group claims that Mars had widespread water, but not in the form of a vast ocean. John Carter of the University of Paris and his colleagues found hydrated silicate minerals inside craters in the northern lowlands of Mars. Such minerals had been found in the planet's southern hemisphere, but this is the first time sites in the northern hemisphere have shown evidence of these materials. The findings appeared June 25 in *Science*.

Carter's group used data from ESA's Mars Express and NASA's Mars Reconnaissance Orbiter to search 91 impact craters where asteroids had exposed ancient material several miles below the surface. Nine contain phyllosilicates or other hydrated silicates, minerals that form in wet environments. "We can now say that the planet was altered on a global scale by liquid water more than 4 billion years ago," says Carter.

So where did all this water go? That's a key question that scientists hope future Mars exploration will answer. In addition, the martian deltas may be a fruitful exploration area for future missions to the Red Planet. "On Earth, deltas and lakes are excellent collectors and preservers of signs of past life," explains Di Achille. "If life ever arose on Mars, deltas may be the key to unlocking Mars' biological past." **— L. K.**



Rivers and lakes. **The martian surface is littered with examples of the presence of water. This delta partially fills Eberswalde Crater in Margaritifer Sinus.** NASA/JPL/Univ. of Arizona

Planetary collisions

NASA announced June 16 that the mysterious flash of light seen June 3 on Jupiter was a meteor burning high above the planet's clouds, disintegrating before it could dive deep enough to leave a plume of debris.

Revealing star births near the Omega Nebula

OMG, Nebula! The Omega Nebula (M17) got a facelift recently with this infrared image from the Spitzer Space Telescope, released July 7. Between 5,000 and 6,000 light-years away in the constellation Sagittarius the Archer, the nebula (bottom center) and a nearby dark cloud called M17 SWex show off their differing stellar formation rates. The cloud forms stars at an impressive rate, but it has yet to create the biggest type of star, called O stars, which light up M17 in droves and have also blown the large "bubble" of gas at the nebula's left edge. — **B. A.** NASA/JPL-Caltech/M. Povich (Penn State Univ.)

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Astronews

Kuiper Belt object details resolved

By taking advantage of a rare sky event, a group of astronomers determined the diameter and reflectivity of a Kuiper Belt object (KBO). The team's findings appeared in the June 17 issue of *Nature*. James Elliot of the Massachusetts Institute of Technology and his colleagues used a network of 21 telescopes to observe KBO 55636 as it occulted, or blocked, a star October 9, 2009. Such occultations can help astronomers determine the size of a planetary object, probe the composition of an atmosphere, and discover planetary rings.

The Kuiper Belt is a system of thousands of rocky and icy objects orbiting the Sun from beyond Neptune's orbit. KBO 55636 is about 40 times the average Sun-Earth span away. Because of its far distance, as the object blocked the star it made a narrow shadow across Earth's surface.

Out of the 21 telescopes, just two — both in Hawaii — had clear seeing and recorded data from the occultation. The team found that KBO 55636 has a radius of 89 miles (143 kilometers), with an uncertainty of plus or minus 3 miles (5 km).

NASA/ESA/G. Bacon (STScI)

Shades of gray. Beyond Neptune's orbit sits the Kuiper Belt, a region of rocky and icy bodies. One such world is shown in this artist's conception. Astronomers recently studied Kuiper Belt object 55636 as it hid a background star.

The object is also highly reflective. Its albedo value is at least 0.82, where 1 is a totally reflective surface. This find is puzzling because astronomers think KBO 55636 is part of the Haumea family of KBOs, which formed about 1 billion years ago after a collision. Space weathering (accumulating dust or hits by cosmic-ray particles) over the past 1 billion years should have darkened their surfaces considerably. The astronomers think the high albedo value of KBO 55636 is a result of one of two things: Either it undergoes some sort of surface restructuring, or fresh water-ice can persist in the outer solar system for billions of years. — **L. K.**

BRIEFCASE

Directly imaged planet confirmed

A team of Canadian astronomers recently re-imaged a planetary system and verified that the object they initially photographed is indeed a companion planet to the young star 1RXS J160929.1–210524. They also obtained data at other wavelengths, which confirm that the planet is about 8.4 times Jupiter's mass and about 1800 kelvin (2780° Fahrenheit). The planet orbits its star at 330 times the distance from Earth to the Sun. — L. K.

Questioning the dark side

Wilkinson Microwave Anisotropy Probe (WMAP) data may not be as accurate as previously thought, according to astronomers at Durham University in the United Kingdom. The group looked at the way WMAP "smoothed" its data maps and found that the smoothing is larger than previously believed. Hence the sizes of the ripples in cosmic background maps might not be accurate. The study, which appeared online July 1 in the *Monthly Notices of the Royal Astronomical Society: Letters*, implies that the model of the universe may not need dark matter or dark energy after all. — L. K.

ESO/A.-M. Lagrange

Peripatetic planet. For the first time, astronomers have visually followed an exoplanet's orbit around a star, as Beta Pictoris b (left arrow in 2003, right arrow in 2009) moves around Beta Pictoris (center).

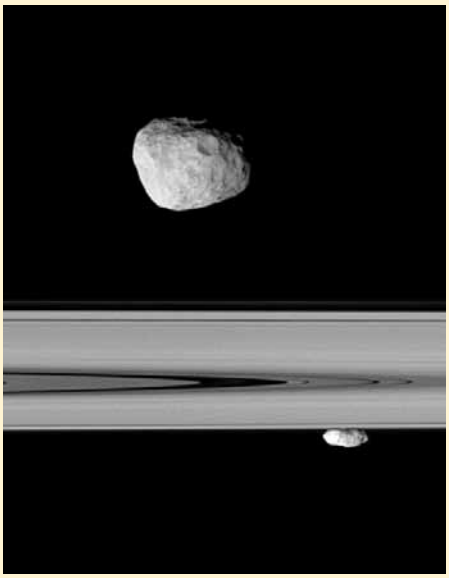
Exoplanet seen moving

Astronomers have witnessed an exoplanet's movements for the first time, according to a July 2 *Science* paper. Orbiting the star Beta Pictoris about 60 light-years away, the gas giant planet (named Beta Pictoris b) appears to have an orbit about the size of Saturn's. Because the star is so young — about 12 million years old — Beta Pictoris b demonstrates that such planets can form in only a few million years, a relatively short time by galactic standards.

Lead author Anne-Marie Lagrange of the Grenoble Observatory in France and her team imaged Beta Pictoris in 2003 and found a faint source of light near the star. The team had been unsure if it was a planet or background star until later images showed the light had disappeared, only to reappear in late 2009 on the other side of Beta Pictoris. — **B. A.**

A star system is born

Astronomers have observed young stars in unprecedented detail to better learn the processes and mechanics of nascent solar systems. The findings appeared July 20 in *The Astrophysical Journal*.



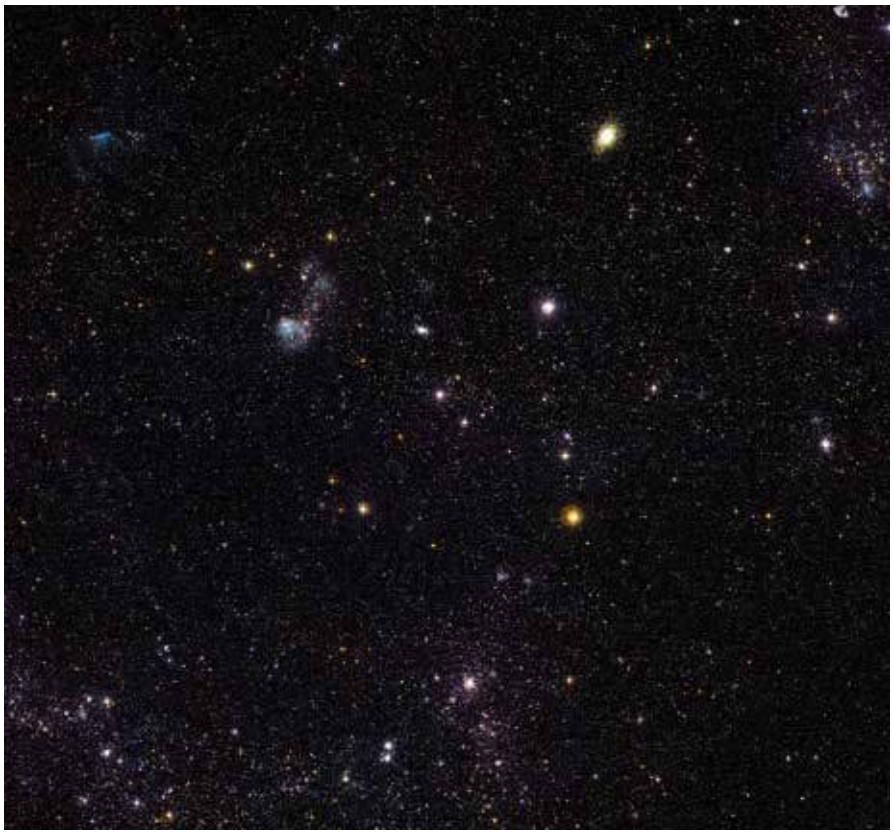
Ring moons. Saturn's small moons Janus (above the ring plane) and Prometheus (below) likely formed from material pushed out of the planet's rings. NASA/JPL/Space Science Institute

Astronomers simulate formation of Saturn's small moons

Among Saturn's rings sit seven tiny moons. They have patchy surfaces and densities lower than water, indicating that they may be "rubble piles," essentially clumps of rock rammed together with voids among the material. These ring moons also are extremely young — about 10 million years old — compared to the solar system's larger bodies, which are 4.5 billion years old. How these moons could have formed has been a question for years, and now Sébastien Charnoz of the Université Paris Diderot and colleagues have determined a possible solution. Their study appeared in the June 10 issue of *Nature*.

The astronomers simulated the evolution of Saturn's rings. They tracked the activity at the ring system's edge and found that they spread outward; after they reached a certain limit, particles were pushed out of the rings' perimeter. Once past the outer rings, the particles would clump, eventually forming larger structures. As these small moons formed, the rings would contract toward Saturn.

The simulation created a ring system and array of small moons that look remarkably similar to Saturn's structure today. The study also implies that the small moons are conglomerations of icy ring particles, which accounts for their low densities. — **L. K.**



New view of neighboring galaxy dazzles

Magellanic menagerie. An image released June 1 from the European Southern Observatory's La Silla Observatory in Chile presents a detailed view of a portion of the Large Magellanic Cloud, one of the Milky Way's closest neighbor galaxies. Various types of objects and phenomena are on display in this 1°-wide view, including a blue reflection nebula at the top left, a bright globular cluster just right of top center, and an open star cluster near the bottom center. — **B. A.** ESO

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Indian affairs

India's Minister of Science and Technology announced June 24 his country's decision to join the Thirty Meter Telescope Project.

ESO (L. Calcada)

Massive work. Astronomers used orbital velocity to determine directly the mass of HD 209458b, a Jupiter-like exoplanet depicted here in front of its host star.

Astronomers directly measure exoplanet mass for first time

Exoplanets, the distant worlds orbiting stars other than the Sun, present a daunting enough challenge to astronomers hoping to spot one, let alone analyze one. Luckily, European astronomers have found a way around this obstacle by discovering a method to measure an exoplanet's mass directly, rather than having to figure it out obliquely by studying the effect the planet has on its star.

Ignas Snellen of the Netherlands' Leiden University and his colleagues report in the June 24 issue of *Nature* how they used orbital velocities and basic physics to calculate the mass of HD 209458b. As it passes in front of its star, about 150 light-years away, the planet's atmosphere absorbs some of its star's light; because the planet moves as it does so, the absorption lines within the star's spectrum exhibit a Doppler shift, just as a moving police siren or galaxy exhibits.

Snellen's team analyzed changes in this Doppler shift to determine the planet's orbital velocity, which allowed them to apply Newton's law of gravity to arrive at the planet's mass. — **B. A.**

ESO/J. Emerson/VISTA. Acknowledgment: Cambridge Astronomical Survey Unit

Peering through Sculptor's dust

Dusty disk. The Sculptor Galaxy (NGC 253) shows off usually hidden details in this European Southern Observatory infrared image, released June 16. The bright spiral galaxy lies some 13 million light-years away in the southern constellation Sculptor, and the thick clouds of dust in its arms typically obscure the goings-on within. Infrared light, however, goes through these clouds almost completely, showing off a horde of cool red stars and a prominent bar spanning the galaxy's center. — **B. A.**

25 years ago in *Astronomy*

October 1985

The October 1985 issue was a special one, devoted to the imminent return of Halley's Comet. Beginning with "Don't Miss Halley's Comet," the editorial staff advised "exactly where and when to look" for the famous visitor. The next return was 76 years away, explaining the staff's calls to action: "The time to start learning the stars along Halley's path is NOW."

Next, in "Space Probes to Comet Halley," the staff looked at the various missions sending spacecraft to rendezvous with the visitor, the first time astronomers could "study a comet up close." Finally, the staff created a collage listing some of the achievements "Since the Last Time …" including 14 presidents, McDonald's, NASA, and "Beam me up, Scotty."

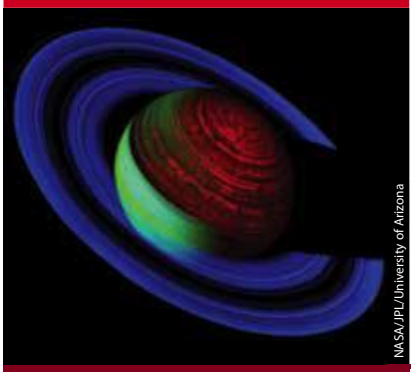
October 2000

10 years ago in *Astronomy*

In the October 2000 issue, science writer and editorial advisory board member Marcia Bartusiak explained how to "Catch a gravity wave." Adapted from her then upcoming book, *Einstein's Unfinished Symphony* (published in December 2000), Bartusiak described the "two sprawling observatories" in Louisiana and Washington that would "test one of Einstein's great theoretical predictions" by searching for gravity waves.

The Laser Interferometer Gravitational-Wave Observatory (LIGO) sites would not come online for another 2 years, and "LIGO researchers concede that their first detectors may not register a thing." Neither site has detected any gravity waves just yet, but hopes remain high, as they did 10 years ago. "If there wasn't a fighting chance," said physicist Peter Saulson of Syracuse University, "I wouldn't be in this field." — **B. A.**

NEXT MONTH
in the November issue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How

An earthlike planet, such as the one in this artist's impression, would provide humanity not only with another wilderness to explore and develop, but also with a potential habitat for alien life. Lynette Cook

astronomers will find another EARTH

Finding an earthlike planet, the first step toward life in the universe, is closer than you might think. **by Debra Fischer**

The race is on to find another Earth. For millennia, it has been a dream of scientists, philosophers, and curious skygazers, and for the first time our species has the ability to search for and find such a planet. But what defines another Earth? What are our prospects for success? How long will it take, and how much will it cost? While we may end up searching for a long time, the answers to these questions have become surprisingly specific.

Finding planets similar to Earth is important because we want to find life out there in the cosmos, and our home planet is the only one we know of that can provide the right conditions to support life. The most important of these conditions seems to be liquid water. Hence the NASA motto: "Follow the water." Earthlike planets are a good bet for finding sustainable oceans of water — and with them, potentially, life.

Debra Fischer *is an astronomer at Yale University in New Haven, Connecticut. She helped discover many of the more than 400 exoplanets we currently know.*

Earthlike planets should be common

In our solar system, there are several small rocky planets and large moons. Venus is the closest thing to a near twin of Earth because of their size similarity. Indeed, if the locations of Venus and Earth had been switched in the architecture of our solar system, Venus could have been our home planet and Earth the hot, waterless world.

If we assume that other solar systems are similar to ours, then we might expect earthlike planets to be relatively common and most stars to harbor more than one rocky world. However, astronomers have not found this to be the case. Within the collection of known exoplanets

Despite their nearly identical size, Earth and Venus vary tremendously, in large part thanks to their differing distance from the Sun. NASA; Magellan Project/JPL/NASA

(planets orbiting other stars than the Sun), hefty worlds with masses similar to Jupiter (318 Earth masses) or Saturn (95 Earth masses) dominate. Scientists have also detected a few dozen planets with masses below Neptune's (17 Earth masses), but no true analogs of Earth have yet turned up.

It's not necessarily true that other Earths aren't there; our search techniques are just not sensitive enough yet to find them. To better understand how to search for planets outside our solar system, we must first consider how the planets in our solar system formed.

Historical perspective

Our Sun formed about 4.6 billion years ago, and the planets, asteroids, and comets in our solar system are simply a trail of debris left behind from the messy details of stellar birth. We can see this same process of solar system formation occurring now among the younger stars in our galaxy.

By studying the heavily cratered surfaces of planets and moons in our solar system, we deduce that a violent phase of bombardment occurred during its early years. The impactors ranged in size from billions of icy micrometeors to a few Mars-sized objects. Planets, moons, and the Sun swept up the vast majority of the leftover disk material, although millions of objects remain even today, loosely gathered in regions like the asteroid belt between Mars and Jupiter. The near-Earth objects (usually asteroids) that we monitor for collisions today are the remaining bits of this "protoplanetary" disk.

Earth's formation, however, leads to a conundrum: Collisions during the heavy bombardment period would have resulted in surface temperatures of about 2000 kelvin (3140° Fahrenheit) and evaporated any surface water off the nascent planet. Where, then, did our oceans come from?

Water, water everywhere …

Water is ubiquitous. Hydrogen is the most abundant element in the universe and oxygen the third most common. So, given the right temperature and pressure, two hydrogen atoms will bond with one oxygen atom and naturally produce H_2O, water. Almost every rocky body in the solar system originally would have contained water in some form. Some of our ocean waters may have been sequestered in Earth's mantle during the heavy bombardment period; however, astronomers believe that impacts from water-rich asteroids after the heavy bombardment period delivered most of the ocean waters.

Water is also volatile. It evaporates, and if exposed to ultraviolet light (as it is in the upper atmosphere), its molecular bonds break apart. The lightweight hydrogen atoms can then achieve escape velocity, leaving the heavier oxygen atoms behind to form ozone (O_3) or carbon dioxide (CO_2), thus drying out the atmosphere.

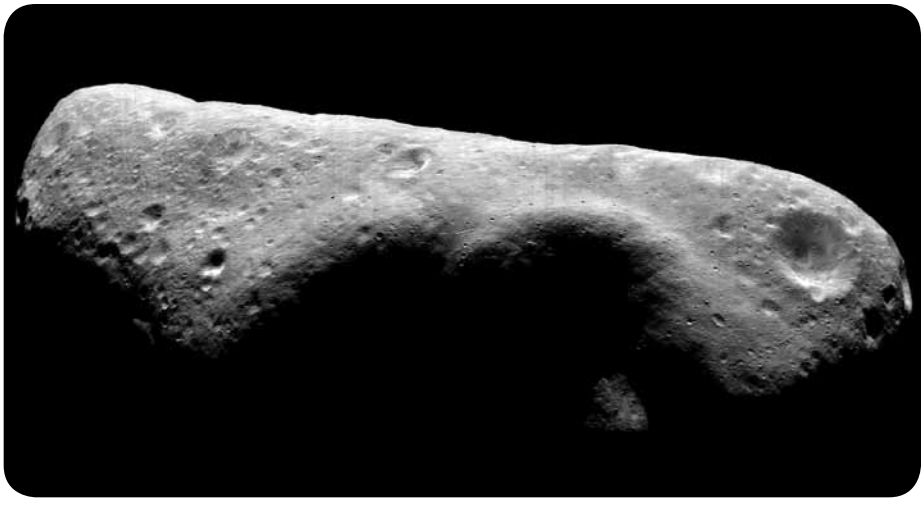
Evidence of this process seems to appear on Mars. Geological patterns on its surface suggest it once had rivers of flowing water. Yet we see no evidence of liquid water today. The planet did not have enough mass to keep a gravitational hold on most of its atmosphere, and without a substantial atmosphere there were no greenhouse gases to keep the planet warm with liquid water.

The only residual water left on Mars is in the form of ice shielded from the heat of the Sun. NASA's Phoenix Mars Lander exposed some subterranean ice in 2008, and images from the ongoing Mars Reconnaissance Orbiter detected water ice in new craters serendipitously carved by recent meteorite collisions. True to theory, though, such fresh ice soon sublimates into the atmosphere, leaving behind little trace of its existence.

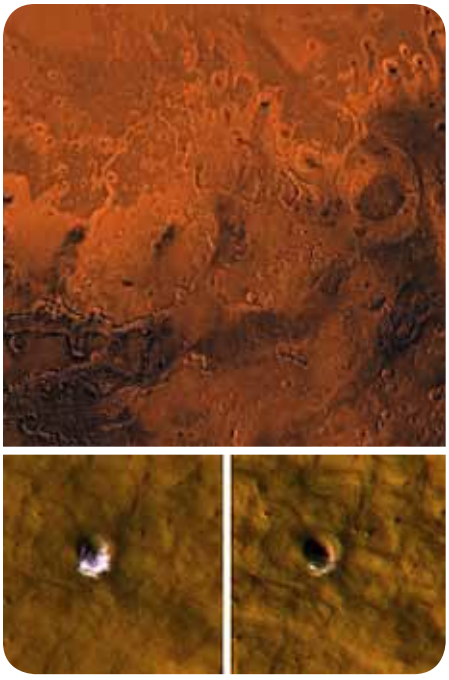
Two important factors help determine whether a planet retains water: its mass and its distance from the host star.

The habitable zone

On Earth, liquid water provides the perfect solvent for organic chemistry, and



Asteroids in our solar system, such as Eros (above), have likely been responsible for causing Earth to lose its original water stores as temperatures soared from multiple collisions, and then delivering the planet its current oceans' worth of water during later impacts. NASA/JPL/JHUAPL



Much evidence points to Mars once having liquid water on its surface, such as the south Chryse basin Valles Marineris outflow channels (top), but the Red Planet's small mass and weak atmosphere prevented it from holding onto that water. Below left, a fresh crater displays water ice newly uncovered from beneath the surface; 3 months later, the same crater appears to have lost most of the ice into the atmosphere and space. NASA/JPL/USGS; NASA/JPL-Caltech/University of Arizona

thus life. Temperature helps determine whether surface water will appear frozen, liquid, or gaseous. Planets orbiting close to the star may be too hot, and those far from it may be ice worlds. Astronomers define this ring of space around a star, where the temperatures permit liquid water on a planet's surface, as the star's habitable zone. Stars smaller and cooler than the Sun have a closer habitable zone and a narrower width. For stars hotter than the Sun, the habitable zone is more distant than Earth's orbit, and it is wider.

Even a slight deviation from this zone can wreck a potential Earth twin's chances for harboring liquid water. Venus has 80 percent of Earth's mass and sits very near the habitable zone without any surface water. Recent observations from the European Space Agency's Venus Express show that proximity to the Sun and the greenhouse effect of the thick venusian atmosphere have accelerated the planet's water loss. Venus is in a water-eroding environment; the ultraviolet intensity breaks apart the molecular bonds of water, and the solar wind removes light hydrogen atoms from the atmosphere.

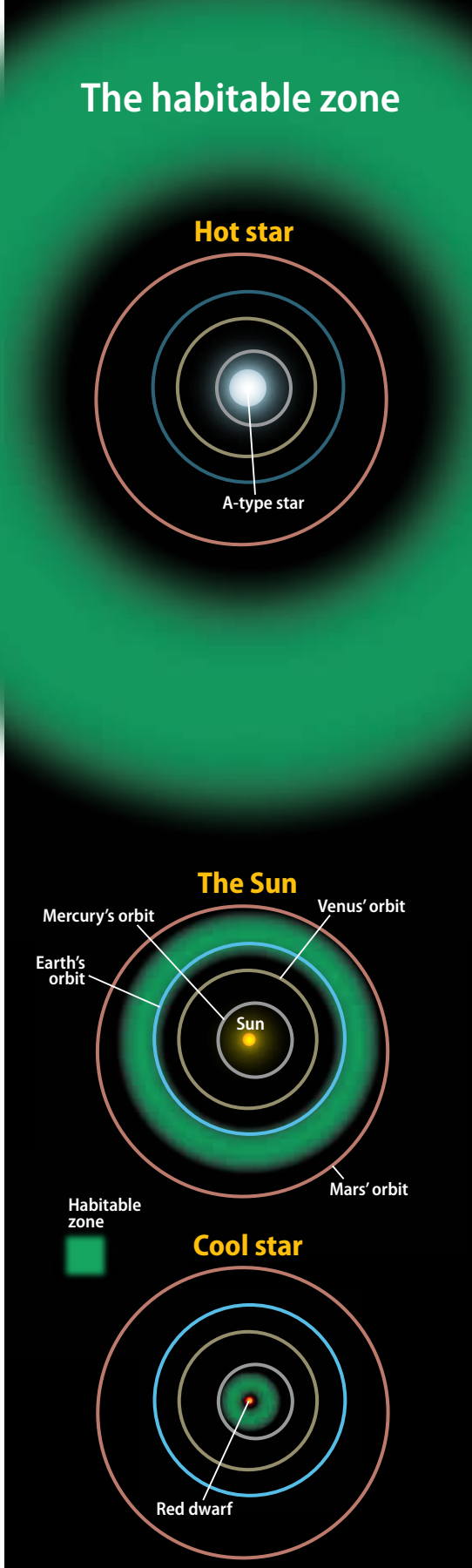
On Earth, liquid water provides the perfect solvent for organic chemistry, and thus life.

Mass matters

The habitable zone is not the only thing that affects a planet's chances of hosting liquid water and life: Its mass is also important. Rocky planets undergo a geological process called "differentiation" where heavy elements like iron and silicates sink toward the planetary core and volatile elements like hydrogen and oxygen outgas to form an atmosphere. During planet formation, this process is a result of the energy of the collisions. At later stages, radioactive decay of heavy elements like thorium and uranium keep the interior of the planet warm and geologically "alive."

A planet's mass also determines how long it will retain internal heat. In Earth's case, the interior heat is critical for maintaining a rotating liquid iron core that spawns a magnetic field, which protects us from the harmful effects of the solar wind. Radioactive decay also provides the energy that drives geological processes like volcanic activity and plate tectonics, which recycle carbon in our atmosphere.

Smaller planets, like Mars, cool more rapidly and have less radioactive material to provide internal heat. With a greater mass, Mars might have maintained its geological processes, a global magnetic field, and plate tectonics. If Mars had been more massive than



A star's habitable zone (in green) is the area around it where a planet could hold liquid water. It's bigger and thicker around hotter stars, and smaller and thinner around cooler stars. *Astronomy:* Roen Kelly

Search the stars

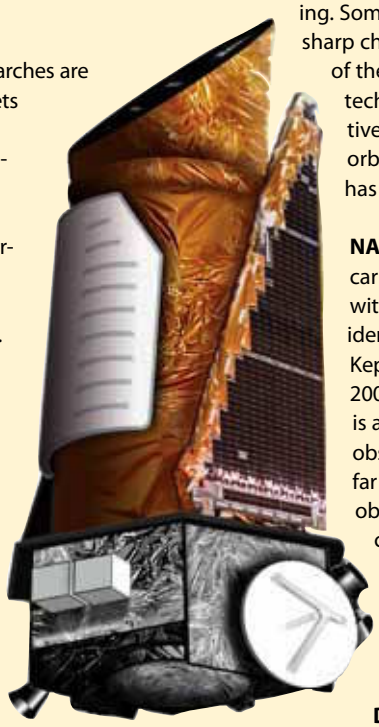
Because Earth is the only planet we know of to have ever supported life, we naturally search for earthlike planets when we search for extraterrestrial life. A variety of search methods exist, and the best results would come about from a combination of them all. These methods are ordered by the approximate dollar cost, starting with the least expensive:

Ground-based transit searches are successful at finding planets down to about the size of Neptune. (A transiting exoplanet is one that crosses directly in front of its star from our point of view.) Targeting smaller stars might allow this technique to detect Earth-sized planets. Although detection requires a relatively uncommon edge-on orientation of the planet system, the work does not need large telescopes, so this method is relatively inexpensive. It's detected scores of transiting planets and can also reveal the size of a planet (and, when combined with radial velocity searches, the mass and density of a planet as well).

Radial velocity searches monitor the back-and-forth wobble of a star. This has been the most successful planet-hunting technique to date, detecting more than 400 planets including several super-Earths around nearby stars. It's most sensitive to massive planets and planets that orbit close to their host stars. Such searches can take place on the ground, so we could begin right away, and the cost is modest compared to space missions.

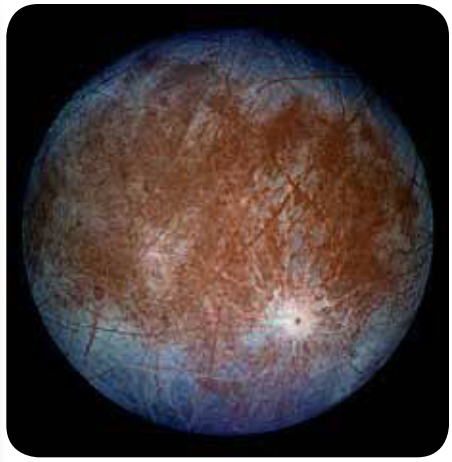
Microlensing surveys are possible when a foreground star with a planet interrupts our line of sight to a more distant star. The nearer star's gravity distorts the farther one's in a process called gravitational lensing. Sometimes this produces sharp changes in the brightness of the background star. This technique is uniquely sensitive to planets in wider orbits, but almost certainly has to take place in space.

NASA's Kepler mission carries out a transit search with enough precision to identify Earth-sized planets. Kepler launched in March 2009, and the planet count is already soaring. The observed stars are relatively far away, making follow-up observations for lifelike conditions challenging; however, this project will reveal whether Earth-sized planets are common or rare.



The Kepler telescope has already discovered numerous planets, in addition to many other scientific contributions, but a true analog of Earth remains elusive. NASA/Kepler mission

Direct imaging is the ultimate goal, and recent developments in technology are on track to make this technique feasible. Direct imaging would eventually produce a picture of a "pale blue dot" orbiting another star, if such a planet exists. With high enough image resolution, we could see clouds rotating across the surface of the planet. With ideal spectral resolution, we could even measure the atmospheric composition. — *D. F.*



Jupiter's moon Europa has managed to hold onto its oceans of water despite its small size because of its great distance from the Sun; it may even hold life, although at this point, scientists can only speculate. NASA/JPL/DLR

Earth, it also might have been able to compensate for its greater distance from the Sun with a more substantial atmosphere. With greenhouse warming, the planet might have maintained a reasonably comfortable surface temperature and liquid water.

Planet mass and orbital distance are both essential in determining a body's potential for water. The jovian moon Europa contains oceans of water, yet this moon is less than 1 percent the mass of Earth — much smaller than Mars. Europa holds on to its endowment of water because its great distance from the Sun keeps its surface water frozen, preventing the escape of subterranean liquid water. If we could drag Europa away from Jupiter, perhaps making a trade for our mostly waterless Moon, the ice would eventually melt and Europa's water would evaporate and escape.

Because our solar system has many examples of rocky planets and moons with less mass than Earth, scientists have a reasonably good understanding of the geological evolution of these objects. But because all are smaller than Earth, the upper limits for a habitable planet's mass are less certain; how big is too big?

It's a relevant question because super-Earths, planets with a mass between 2 to 10 times our world's, have already begun turning up in exoplanet searches. These planets will almost certainly have more geological activity. No one is sure what this will mean for surface water.

Time matters

As a result of Earth's unique attributes — mass, temperature, chemical composition, and a global magnetic field — its oceans have persisted for more than 4 billion years, and life has existed for about 75 percent of that time. It is plausible that the first life on Earth may have used and "fed off" the energy of underwater thermal vents, where the deep oceans would have provided a protective shield against changing climate and deadly impacts. Of course, such life did not (and could not) leave behind a fossil record, so it's impossible to know for sure.

Geochemical records and fossils show that early life at the ocean-air boundary harnessed the Sun's energy through photosynthesis. It took about half of Earth's lifetime to modify the atmosphere to produce the oxygen-rich air we breathe today. About 500 million years ago (roughly the

last tenth of Earth's existence), the Cambrian explosion ushered in an unprecedented diversity of complex life-forms. Then, recently — in just the past 0.02 percent of Earth's existence — humans appeared. Our technological civilizations have only been around for about one-thousandth of our already brief history.

Our presence on Earth cannot continue forever. Computer models by Jim Kasting at Penn State University show that Earth's oceans will evaporate in the next billion years (unless we take protective measures somehow, such as building a solar shield). In the end, our habitable home world may turn out to be uninhabitable for half of its lifetime.

When we find other "habitable" worlds, will they be inhabited when we observe them? Perhaps we will detect them before life has evolved or after life has perished. The challenges for the evolution of life and the long-term retention of a suitable environment suggest that we need a large set of earthlike planets to carry out a statistically significant search for life on other worlds.

The search begins

Various techniques exist to find earthlike planets capable of supporting liquid water (see "Search the stars," page 32), each with its assets and liabilities. In order to assemble a complete picture, we must combine them all, and it will take 10 to 20 years to acquire a large sample of earthlike planets. The choice of one technique at the expense of others would be an unwise compromise. But can our society afford such an ambitious program as this ideal? A rough cost estimate to "do everything" is about $7 billion, less than half of NASA's entire annual budget.

For perspective, Americans spent about $15 billion for bottled water in 2007 — more than twice the amount necessary for an ambitious search for other Earths. If we spent just half as much on exoplanet searches as we spent on bottled water, we could fund the search for water on other planets — a worthy and exciting goal.

The motivation to find earthlike planets stems from our desire to answer the age-old question: Does life exist elsewhere in the universe?

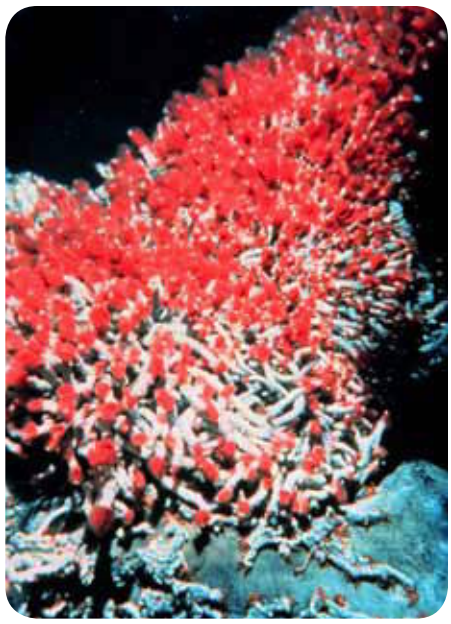
Why we search

The motivation to find earthlike planets stems from our desire to answer the age-old question: Does life exist elsewhere in the universe? Earthlike planets really should be similar to Earth; they need to be similar in mass and they need to orbit within a star's habitable zone where liquid surface water could survive for billions of years. The detection of these earthlike planets would provide ideal places to search for signs of life; it would be relatively simple to look for chemical signatures in the atmospheric spectra that indicate the presence of vegetation, animals, or even technological civilizations.

The implications of finding life on other worlds are profound. The discovery of the first planet orbiting a Sun-like star, 51 Pegasi b in 1995, revealed key differences between exoplanets and planets in our solar system and helped us tune up our observing strategies and detect hundreds of other planets.

The same phenomenon may occur in the search for life: Once we detect life on one planet, we may realize how to find life on many worlds. Perhaps we will learn that other earthlike worlds rarely harbor life. Perhaps we will learn that life is common. A discovery of even simple extraterrestrial life will surely have deep ramifications for creatures on Earth, impacting our philosophies, religions, art, and science.

Finding extraterrestrial life would be momentous, and we might be able to do it for less than we spend on bottled drinking water in 1 year.



The earliest life on Earth may have arisen near underwater thermal vents, similar to these tubeworms feeding at the base of a black smoker chimney hydrothermal vent. OAR/National Undersea Research Program

The aurora borealis, or northern lights, glimmers above Alaska's Bear Lake, a reminder of the protection Earth's atmosphere and magnetic field offer from the solar wind. Such phenomena may be necessary side effects for life-sustaining environments. United States Air Force Senior Airman Joshua Strang

Read "How do you make a giant exoplanet?" at www.Astronomy.com/toc.

Inside our home supercluster

Our Local Group of galaxies is but one small cog in the vast wheel of the Virgo supercluster.

by Richard Talcott; illustration by Roen Kelly

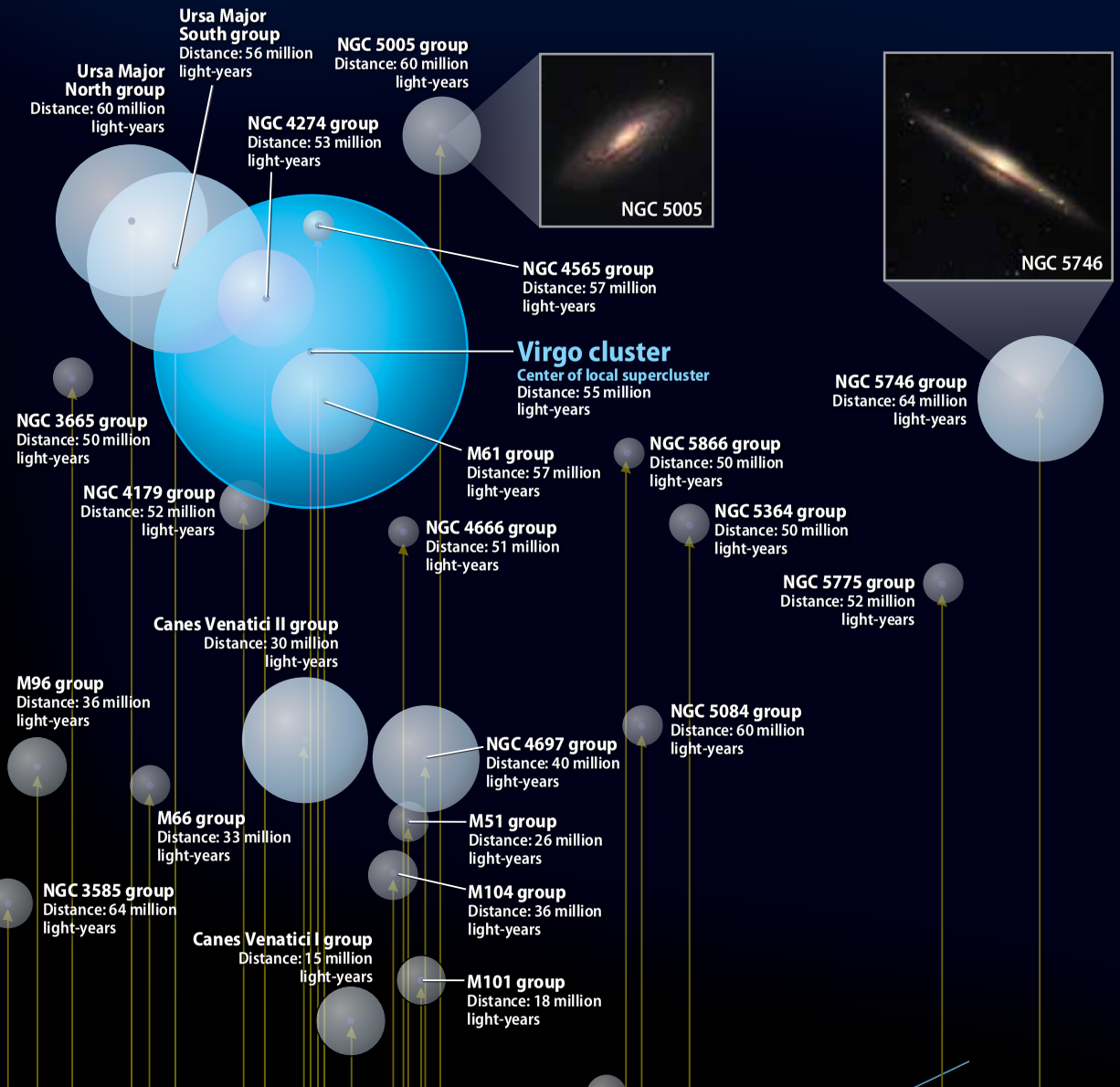
Astronomers long ago realized that deep-sky objects aren't spread evenly around the sky. French comet-hunter Charles Messier (1730–1817) compiled a catalog of "nebulous objects" and found a high concentration along the Milky Way, where open star clusters and the star-forming regions that spawn them congregate. (In the telescopes of Messier's time, all these objects appeared nebulous.)

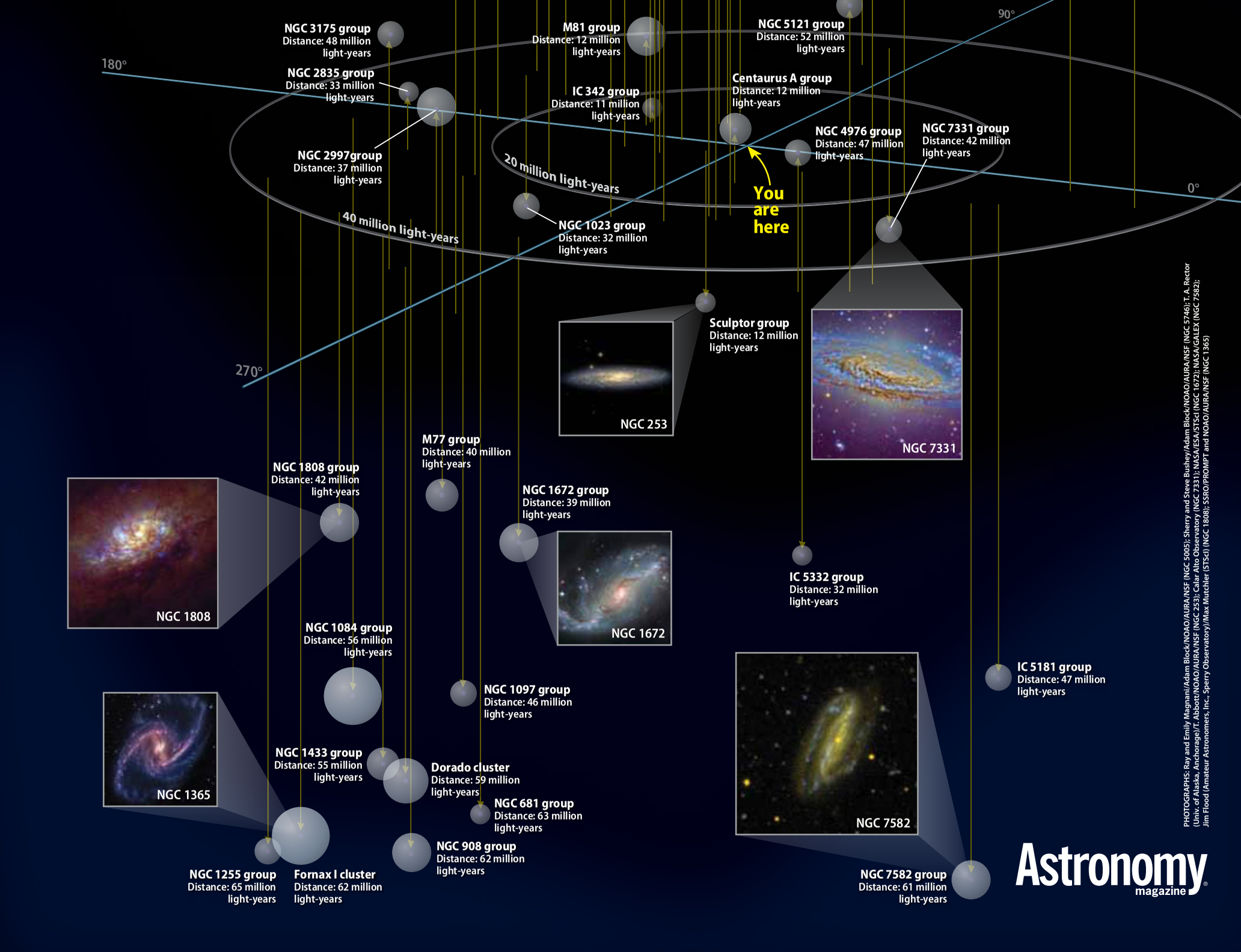
But Messier also found a peculiar excess of 16 objects near the border between the constellations Virgo and Coma Berenices. Later, observer William Herschel (1738–1822) and his son, John (1792–1871), cataloged more than 200 "nebulae" in this same area. It wasn't until the 1920s and '30s, however, that astronomers realized these objects were full-fledged galaxies that formed a cluster far beyond the Milky Way.

In the 1950s, French-born astronomer Gérard de Vaucouleurs (1918–1995) recognized that a halo of galaxies surrounding the so-called Virgo cluster extended all the way to our Local Group of galaxies, which the Milky Way calls home. He initially called this complex the Local Supergalaxy, but later changed it to the Local Supercluster.

Our home supercluster extends more than 50 million light-years from its Virgo cluster center. In this illustration, we show the part of the supercluster extending from the Local Group (located at the map's center but in reality near the supercluster's edge) to slightly beyond the Virgo cluster. The graphic includes all galaxy groups and clusters containing at least three relatively large galaxies. The size of each sphere reflects the number of galaxies in the group or cluster. The map also lists the approximate distances from Earth to our neighbors.

Richard Talcott *is a senior editor of* Astronomy *and author of* Teach Yourself Visually Astronomy *(Wiley Publishing, 2008).*





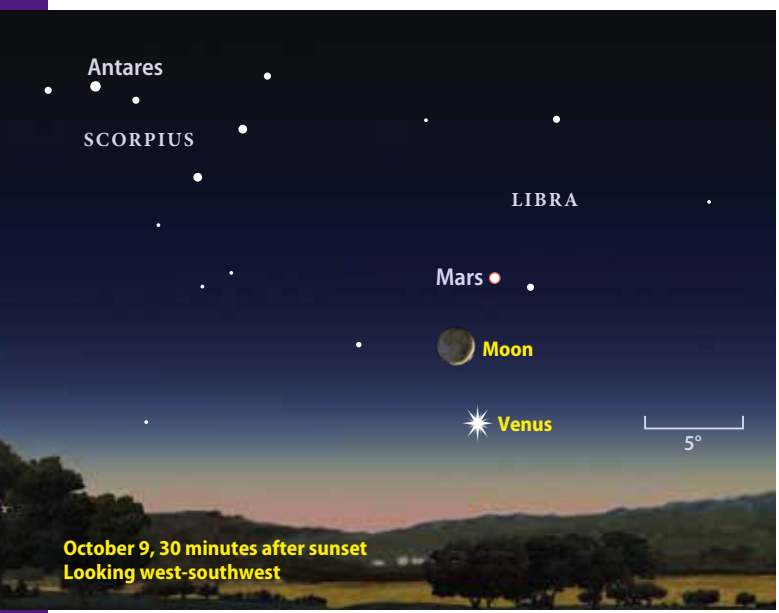
PHOTOGRAPHS: Ray and Emily Magnani/Adam Block/NOAO/AURA/NSF (NGC 5005); Sherry and Steve Bushey/Adam Block/NOAO/AURA/NSF (NGC 5746); T.A. Rector (Univ. of Alaska, Anchorage)/T. Abbott/NOAO/AURA/NSF (NGC 253); Calar Alto Observatory (NGC 7331); NASA/ESA/STScI (NGC 1672); NASA/GALEX (NGC 7582); Jim Flood (Amateur Astronomers, Inc., Sperry Observatory)/Max Mutchler (STScI) (NGC 1808); SSRO/PROMPT and NOAO/AURA/NSF (NGC 1365)

The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

October 2010

Jupiter shines big and bright



The Moon swings above Venus at dusk October 9. You'll need a flat horizon and clear skies to see the pair. *Astronomy:* Roen Kelly

One dark belt was all Jupiter could muster early this year. Scientists don't know how long the planet's second dark belt will remain missing. Anthony Wesley

The beginning of autumn in the Northern Hemisphere brings more time to observe under a canopy of darkness. Unfortunately, the solar system's major planets don't participate fully in the added viewing hours. Only Jupiter shines brightly nearly all night. With a large disk, an active atmosphere, and four bright moons, giant Jupiter provides endless fascination for those who view it through a backyard telescope.

Uranus lies along nearly the same line of sight as Jupiter. The more distant planet remains an easy binocular object all month. Neptune glows fainter than Uranus and lies significantly farther west, so it shows up best during the evening hours.

The other planets put in only brief appearances this month. Venus and Mars shine in evening twilight but disappear from view less than an hour after sunset. And Saturn reappears shortly before dawn after mid-October.

Let's begin our night sky excursion in early October some 30 minutes after the Sun sets. If you look low in the southwest, you should spot **Venus**. Although it lies only a few degrees above the horizon from mid-northern latitudes, the planet appears so bright that you can glimpse it in bright twilight if you have a clear sky and a flat southwestern horizon. Venus lies a little higher in the twilight sky the farther south you live.

On October 1, Venus shines brilliantly at magnitude –4.8, about 100 times brighter than any autumn evening star. The view through a telescope dazzles. Venus spans 45" and shows a thin crescent slightly less than 20 percent lit. Don't waste any time, however — the planet sets 50 minutes after the Sun goes down.

Venus sinks closer to the horizon with each passing night. But you should still mark your calendar for October 9, when a slender crescent Moon joins a hard-to-see Venus. The planet hangs just below the 7-percent-lit Moon.

— *Continued on page 41*

36 The Moon visits Venus
36 Jupiter loses its belt
41 Meteor watch
41 Rising Moon
42 When to view the planets
42 Two shadows transit Jupiter
42 Comet search
43 Locating asteroids
43 Saturn returns before dawn

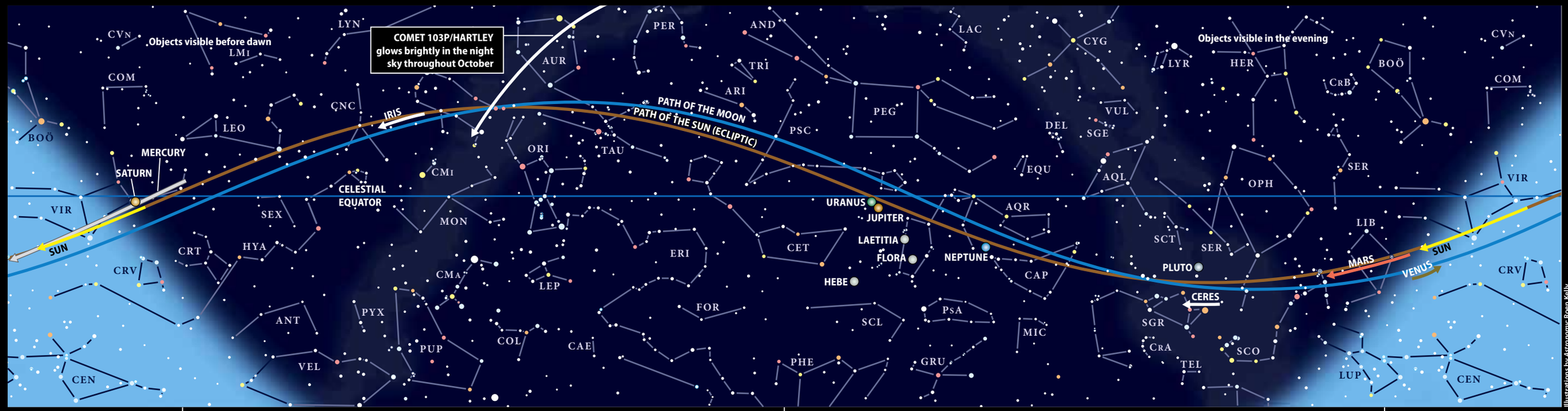
Visible to the naked eye
Visible with binoculars
Visible with a telescope

Planets in October 2010

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets

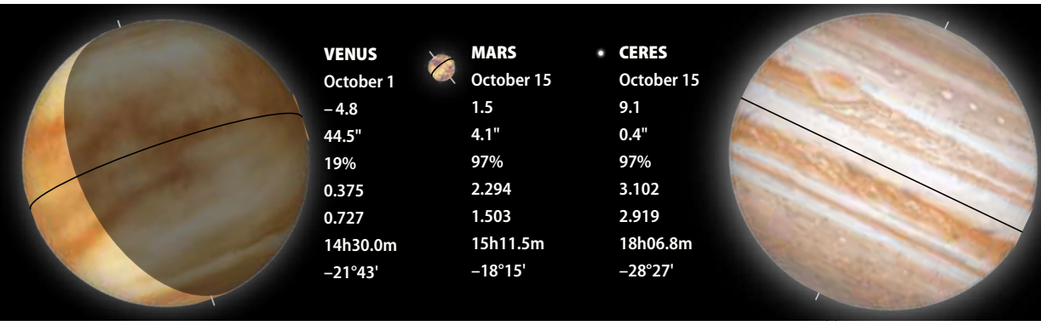


Illustrations by *Astronomy*: Roen Kelly

MOON PHASES

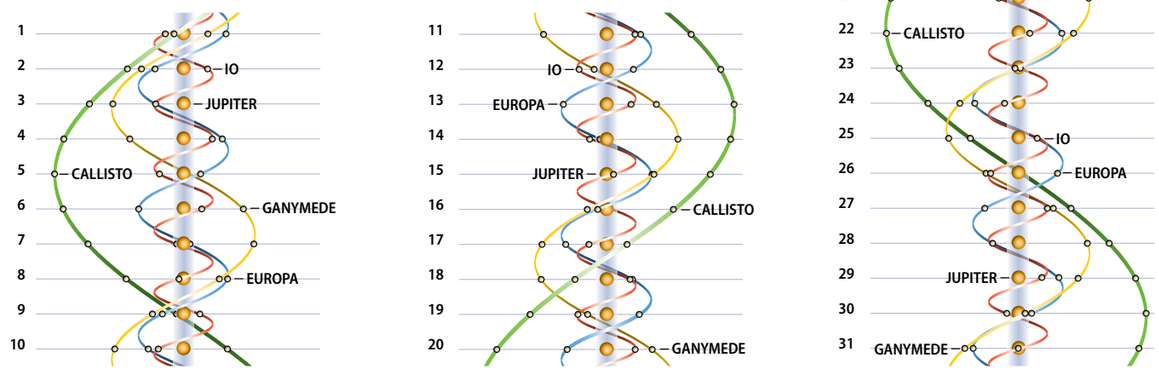
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

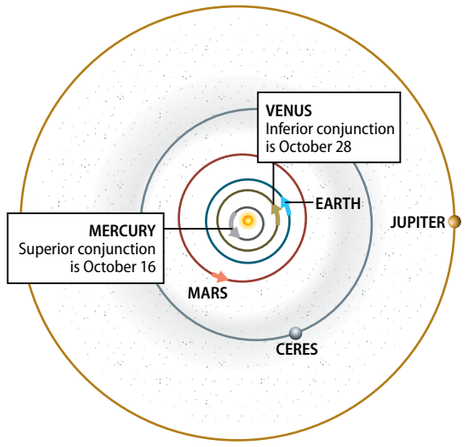
PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	October 1	October 1	October 15	October 15	October 15	October 31	October 15	October 15	October 15
Magnitude	–1.1	–4.8	1.5	9.1	–2.9	0.9	5.7	7.9	14.1
Angular size	5.5"	44.5"	4.1"	0.4"	48.8"	15.9"	3.7"	2.3"	0.1"
Illumination	88%	19%	97%	97%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.232	0.375	2.294	3.102	4.040	10.448	19.175	29.440	32.215
Distance (AU) from Sun	0.334	0.727	1.503	2.919	4.955	9.566	20.092	30.016	31.914
Right ascension (2000.0)	11h45.4m	14h30.0m	15h11.5m	18h06.8m	23h45.3m	12h44.7m	23h52.2m	21h53.3m	18h12.1m
Declination (2000.0)	3°38'	–21°43'	–18°15'	–28°27'	–3°19'	–2°25'	–1°42'	–13°21'	–18°41'



Jupiter's moons

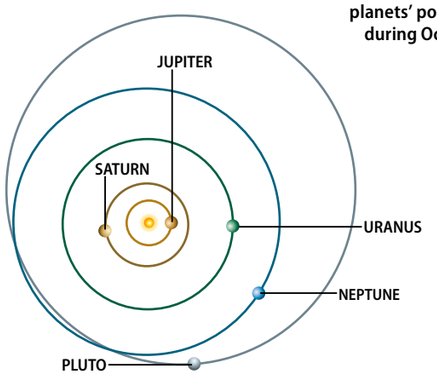
Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown.
South is at the top to match the view through a telescope.





The planets in their orbits

Arrows and dots show planets' positions during October.



StarDome

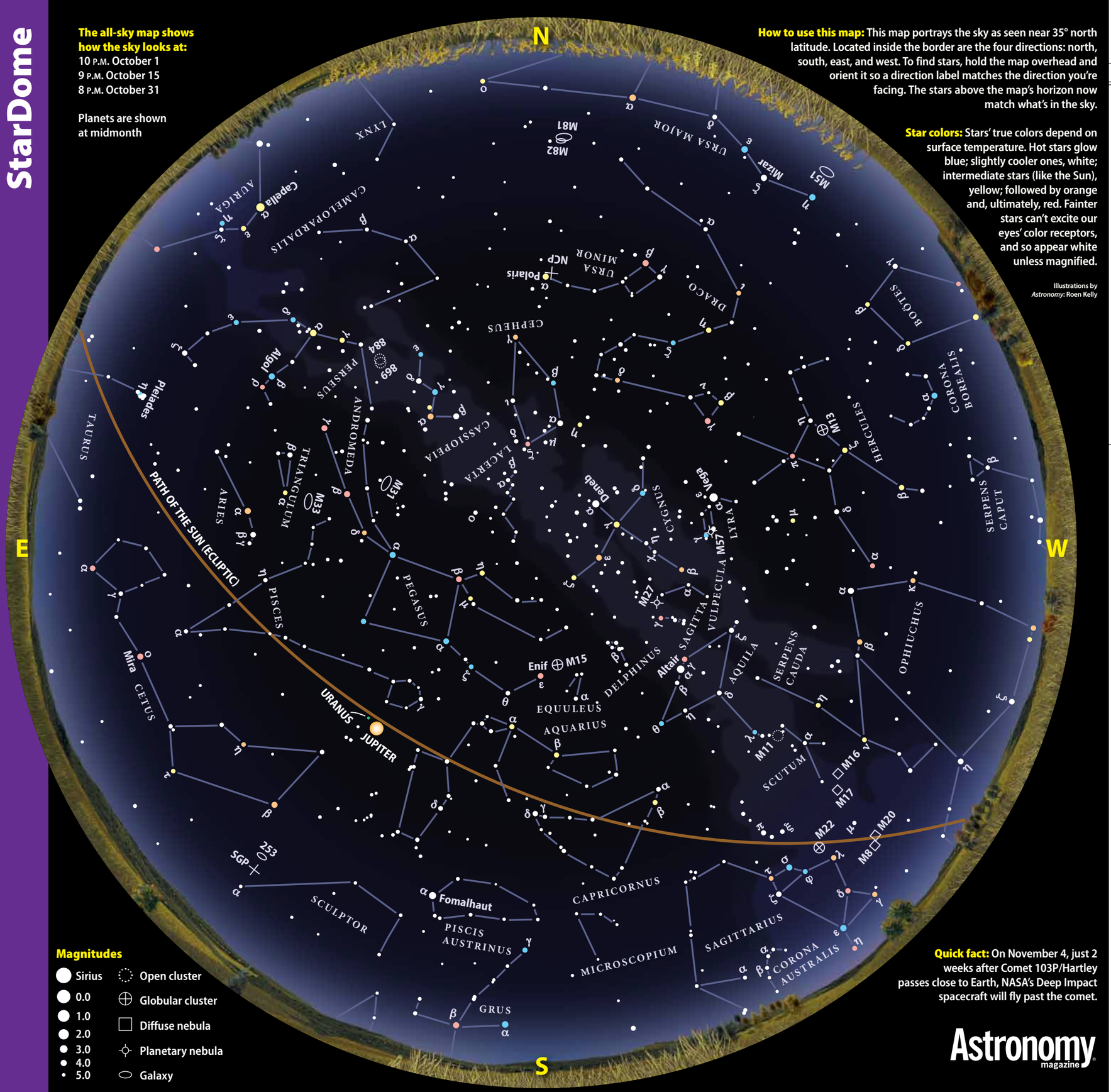
The all-sky map shows how the sky looks at:
10 P.M. October 1
9 P.M. October 15
8 P.M. October 31

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: On November 4, just 2 weeks after Comet 103P/Hartley passes close to Earth, NASA's Deep Impact spacecraft will fly past the comet.

Astronomy magazine

October 2010

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Calendar of events

6 The Moon is at perigee (223,355 miles from Earth), 9:38 A.M. EDT

7 New Moon occurs at 2:44 P.M. EDT

Venus is stationary, 3 P.M. EDT

9 The Moon passes 3° north of Venus, noon EDT

The Moon passes 4° south of Mars, 10 P.M. EDT

14 First Quarter Moon occurs at 5:27 P.M. EDT

16 Mercury is in superior conjunction, 9 P.M. EDT

17 The Moon passes 5° north of Neptune, 6 P.M. EDT

18 The Moon is at apogee (251,921 miles from Earth), 2:17 P.M. EDT

20 The Moon passes 7° north of Jupiter, 7 A.M. EDT

The Moon passes 6° north of Uranus, 11 A.M. EDT

Comet 103P/Hartley passes closest to Earth (11.2 million miles away), 1 P.M. EDT

Special observing date

20 Comet 103P/Hartley reaches its peak in October, when it may glow bright enough to see with naked eyes under a dark sky.

21 Orionid meteor shower peaks

22 Full Moon occurs at 9:37 P.M. EDT

28 Venus is in inferior conjunction, 9 P.M. EDT

30 Last Quarter Moon occurs at 8:46 A.M. EDT

See tonight's sky in Astronomy.com's STARDOME

— *Continued from page 36*

A telescope reveals Venus to be 11 percent lit with a diameter of 51". (To avoid accidentally frying an eyeball, wait until after sunset to view the planet.) Venus disappears from view within the next few days as it heads toward its October 28 inferior conjunction, when it passes between the Sun and Earth.

Mars is a mere footnote in the evening sky this month. It glows at magnitude 1.5 and barely shows up against the bright twilight. It lies 6° to Venus' upper right October 1, and 3° to the Moon's upper right October 9. On both evenings, binoculars will help you spot Mars' ruddy glow.

Shortly after the sky grows completely dark, you can locate **Neptune** in the southern sky, but you'll need binoculars or a telescope to see its 8th-magnitude glow. Neptune lies in the northeastern corner of Capricornus the Sea Goat. You'll find the planet some 3° northeast of that constellation's brightest star, Delta (δ) Capricorni, and it will show up in the same binocular field of view.

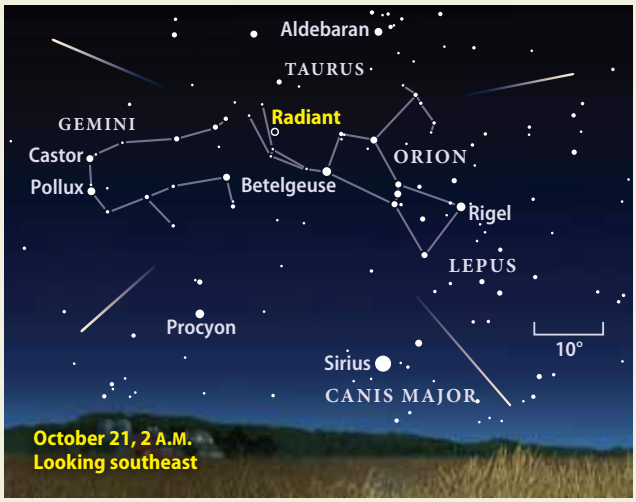
Neptune lies even closer to 5th-magnitude Mu (μ) Capricorni. The objects remain near each other throughout October, with the planet passing 0.2° north of the star October 14. If you turn a telescope on Neptune and crank the magnification past 100x, you'll see the planet's 2.3"-diameter disk and subtle blue-gray color.

As befitting its moniker "king of the planets," **Jupiter** reigns supreme nearly all night. You can spot the planet above the southeastern horizon shortly after the Sun goes down. It shines at magnitude –2.9, making it the brightest point of light in the sky once Venus sets.

Jupiter spends the first half of the month in the constellation Pisces the Fish before crossing into Aquarius the Water-bearer around mid-October. The giant planet reached opposition and peak visibility in late September, which was its finest appearance in nearly half a century.

Martin Ratcliffe *provides professional planetarium development for Sky-Skan, Inc., in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Orionid meteor shower peaks before dawn October 21. This year, the meteors have to battle a nearly Full Moon. *Astronomy:* Roen Kelly

On the hunt for Halley's debris

The annual Orionid meteor shower peaks October 21. Unfortunately, the Moon reaches its full phase just a day later, and its light will drown out all but the brightest meteors. The shower remains active from October 2 to November 7, so you might see a few Orionid meteors during the early morning hours in mid-October. If you do, you are witnessing dust grains burning up high in Earth's atmosphere that Comet 1P/Halley ejected during its innumerable trips through the inner solar system.

October also hosts a notable minor meteor shower. The Draconids peak October 8, a day past New Moon, so viewing conditions should be good. Draconid meteors travel slowly, at "only" 12 miles per second, so it's pretty easy to tell them apart from typical sporadic meteors. While this shower typically doesn't amount to much, it occasionally puts on a decent show with counts reaching 10 to 30 meteors per hour. Unfortunately, astronomers don't expect one this year.

Rising Moon

Spin and twirl on the lunar limb

The crater named after rocketry pioneer Robert Goddard arcs past the Moon's eastern limb in just a few nights this month. Watching it disappear offers a nice lesson in how our satellite rotates.

On the evening of October 10, the Moon's fat crescent displays lots of real estate between the eastern limb and the large oval of Mare Crisium. The darker patches along the limb are hardened lava belonging to Mare Marginis, the Sea on the Margin.

A short white arc just beyond the sea's eastern shore is the lit rim of Goddard. During the next several nights, the Moon's eastern limb appears to roll away from us. On the 15th, Goddard appears in profile, with its rim poking out as two peaks framing a darker middle.

By October 18, Goddard has disappeared over the limb and Mare Marginis itself is half gone. At full phase October 22, a few bumps of this mare's shoreline remain, and the prominent Mare Crisium appears much closer to the limb.

The reason for this lunar sleight of hand? The Moon spins at a steady pace, completing one rotation on its axis each month. In the same time frame, however, our satellite orbits Earth on an elliptical path, so its speed of revolution varies. Observers thus can see a few degrees beyond the normal limb at certain times each month. Astronomers call this effect libration.

The dark floor of Goddard Crater lies near the lunar limb in mid-October, when the Moon's eastern edge tilts toward Earth. *Consolidated Lunar Atlas*/UA/LPL

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Venus (southwest)	Jupiter (south)	Mercury (east)
Mars (southwest)	Uranus (south)	Saturn (east)
Jupiter (southeast)	Neptune (southwest)	
Uranus (southeast)		
Neptune (southeast)		

Needless to say, it remains superb in October.

Small telescopes show a wealth of detail on Jupiter, particularly when it appears big. And it's huge in early October. On the 1st, the giant planet spans 49.7" across its equator, just 0.2" less than its late-September maximum.

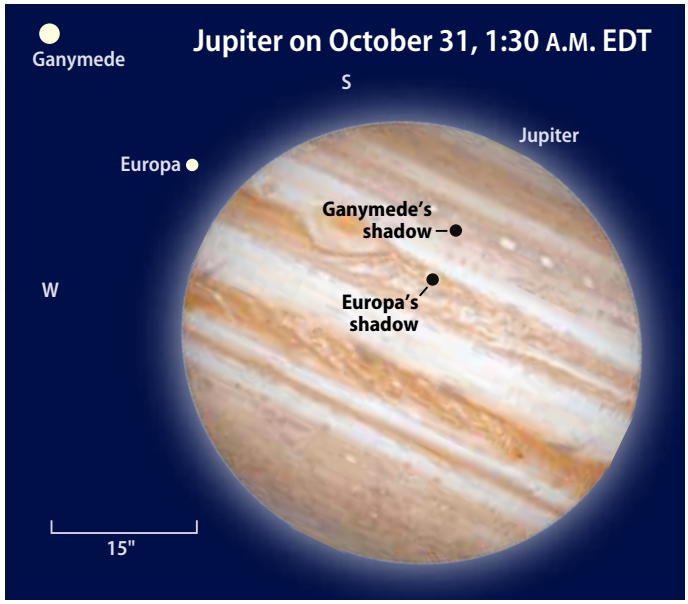
If you stare at Jupiter through your scope for a minute, you'll notice that it appears slightly squashed. This is not an illusion. On the 1st, the planet's apparent diameter through its poles is 3.2" less than its equatorial diameter. Jupiter's rapid rotation and gaseous nature cause this discrepancy. Jupiter remains a big target throughout October. Even by the 31st, it measures a healthy 47.1" across the equator.

The best views of jovian atmospheric features come when the planet lies high in the sky, so wait until late evening to see the sharpest details. The first feature you'll likely see is the North Equatorial Belt (NEB), a dark band that crosses the planet just north of its equator. On the opposite side of the equator, you may see the thin dark line of the South Equatorial Belt (SEB). The SEB used to resemble the NEB closely, but now it appears as a narrow echo of its former breadth. Perhaps an SEB revival awaits before Jupiter disappears into the Sun's glow next March.

Dark belts are relatively warm, deep cloud layers, and the brighter zones that flank them are cooler and higher. A close inspection of the belts' edges often reveals turbulent cloud features. Remember that Jupiter is 11 times the diameter of Earth, so even small features visible through a telescope are huge by terrestrial standards.

In addition to the equatorial belts and zones, more subtle banding appears at higher jovian latitudes. None of these features stands still because Jupiter spins so fast. The giant planet completes a rotation in slightly less than 10 hours, so you can see three-quarters of the planet in just 2.5 hours.

As fascinating as Jupiter's atmosphere can be, many observers enjoy viewing the planet's four brightest moons just as much. From our earthly perspective, these moons wander back and forth as they circle Jupiter. Each of the inner three moons — Io, Europa, and Ganymede — crosses the planet's disk when



A pair of dark spots crosses Jupiter the night of October 30/31, when the shadows of Europa and Ganymede transit the planet's disk. *Astronomy*: Roen Kelly

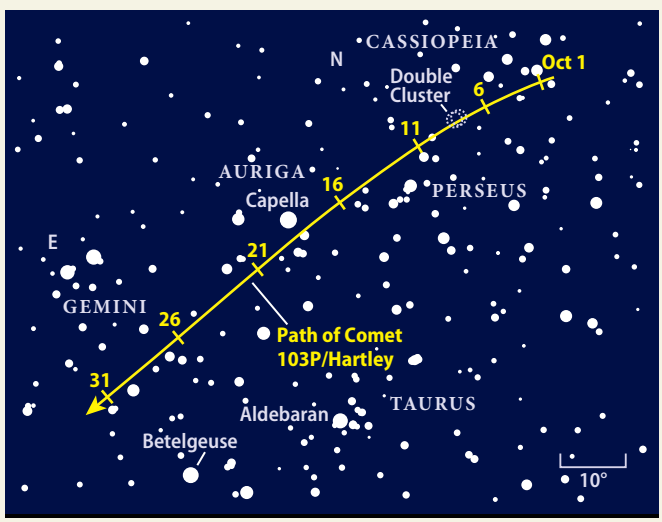
Comet search

Track the brightest visitor of the year

Have you ever seen a comet with just your eyes? Although Comet 103P/Hartley won't deliver quite the thrill that Comet C/1995 O1 (Hale-Bopp) did in 1997, it should be a memorable sight under a dark sky. Astronomers expect Comet Hartley to peak near 5th magnitude in October, when it will look like a silver sword hanging beneath the majestic W of Cassiopeia the Queen. This region lies high in the northeast these October evenings.

Compare Hartley with the Andromeda Galaxy (M31), which lies about 15° to the comet's south. Does the comet glow brighter or fainter than the galaxy? Does it appear sharper or fuzzier? As October begins, Hartley lies near the Pacman Nebula (NGC 281). And with perfect timing for the New Moon weekend of October 9, the comet floats next to the Double Cluster in Perseus (NGC 869 and NGC 884).

Enjoy the sight with binoculars, and then target Hartley with a telescope. Pump up the power to view the straight gas tail, which could show some blue-green color through large scopes. The gray-white dust tail spreads out in a narrow "fan" from the central coma. This fan tilts from night to night until October 28, when it appears edge-on. The comet then lies in Gemini, not far from the gibbous Moon.



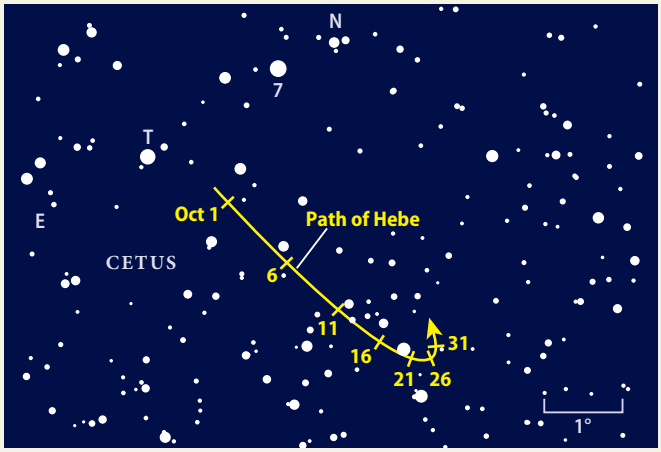
Search for Comet 103P/Hartley as it hangs high in the evening sky during October. The brightest comet of 2010 may be visible with naked eyes under a dark sky. *Astronomy*: Roen Kelly

Meteorite chips off the old block

A long time ago, two asteroids collided. Chunks of rock sprayed out to form a huge cloud of shrapnel. Millions of years later, these space rocks flamed across Earth's skies one by one. Scientists collected the remains of these "falling stars" and traced them back to their parent object: asteroid 6 Hebe. Astronomers figure that 40 percent of Earth's meteorites share this story of genesis from Hebe, based on their common characteristics under the microscope and spectroscope.

There is still plenty of Hebe left for observers to see. The asteroid spans about 120 miles and reflects enough sunlight to glow at 8th magnitude. From a suburban backyard, point your scope at the 2nd-magnitude star Beta (β) Ceti, which lies southeast of Jupiter in the southern sky these October evenings. Then, skip westward to 7 Ceti and star-hop 2° south to Hebe.

To be sure you've identified the asteroid and not a background star, note the positions of the objects near Hebe and return a few hours later. The asteroid will have moved relative to the stars.



Asteroid Hebe glides through Cetus the Whale this month, not far south of the 4th-magnitude star 7 Ceti. *Astronomy*: Roen Kelly

the moon's orbital motion brings it between Jupiter and Earth. A short time later, the moon's shadow crosses the jovian disk. The black shadows show up more clearly because they have greater contrast with Jupiter's bright cloud tops. (The outermost major moon, Callisto, passes just above and below the planet's disk as it orbits.)

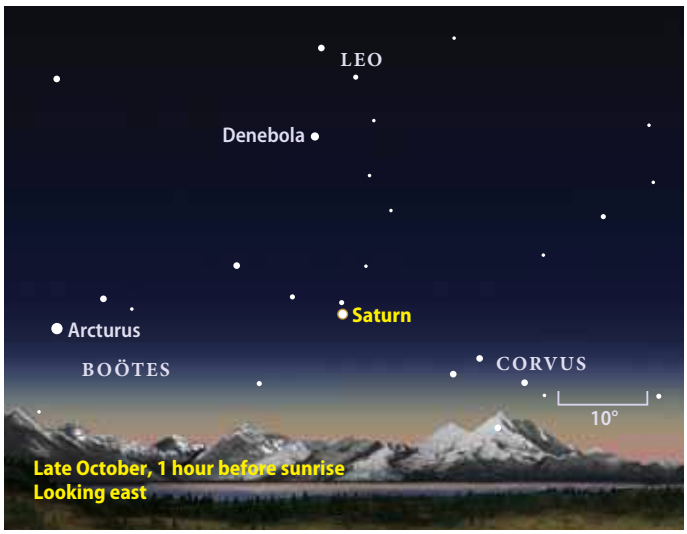
The night of October 30/31 offers a great opportunity to watch two moons and their shadows transit Jupiter. Ganymede begins the performance when it starts to transit Jupiter at 8:21 P.M. EDT. (This opening act won't be visible from the western half of North America, but the rest will be.) Europa follows Ganymede across the jovian disk some 2 hours later, starting at 10:26 P.M. EDT. After Ganymede completes its transit at 11:20 P.M. EDT, it and innermost Io hang just off Jupiter's western limb for the next 16 minutes. That scene comes to an end when Io passes behind the planet's disk at 11:36 P.M. EDT.

The action picks up at 12:09 A.M. EDT when Ganymede's shadow appears on the planet's eastern limb. Europa's shadow joins Ganymede's just 7 minutes later. Europa itself transits Jupiter's disk until 1:09 A.M. EDT. The conspicuous shadows continue their transits until 2:59 A.M. EDT (Europa) and 3:07 A.M. EDT (Ganymede).

A small telescope is all you need to view Jupiter's cloud tops and the moons' transits. But aim your 7x50 binoculars at the giant planet and you'll get an unexpected treat: **Uranus** lurks within the same field of view. Uranus lies 1.4° northeast of Jupiter October 1; the gap grows to 3.2° by the 31st. Glowing at magnitude 5.7, Uranus shows up easily through binoculars. Just don't confuse it with the slightly brighter background star 20 Piscium, which lies between the two planets after October's first week.

You'll need a telescope to confirm Uranus as a planet. At medium magnification, its 3.7"-diameter disk and blue-green hue appear conspicuous. Although it lies near Jupiter in the sky, Uranus is nearly 5 times farther from Earth, at a distance of 1.8 billion miles.

Although **Saturn** was in conjunction with the Sun in late September, it returns to view before dawn in October's second half. By the 31st, it rises more than 2 hours before the Sun and appears low in the east as twilight starts to paint the sky. Saturn shines brightly at magnitude 0.9. Don't confuse it with Arcturus, a brighter star that appears near the same altitude as Saturn but significantly farther to the north.



Saturn returns to view before dawn late this month. Look for the ringed planet low in the eastern sky. *Astronomy*: Roen Kelly

Don't expect Saturn to look like much through a telescope. Its low altitude as dawn approaches means its light has to pass through more of Earth's image-distorting atmosphere. If you do look, you'll likely get a blurry view of the planet's 36"-diameter rings. Observing conditions will improve significantly by next month.

Mercury rises due east an hour before the Sun October 1 and appears 5° high 30 minutes later. At magnitude –1.1, it shines bright enough to see through the twilight, although it was higher and easier to see during September's final 2 weeks. The innermost planet quickly drops out of sight. How far into October can you follow it?

Explore the PUL

Astronomers are discovering many strange properties of compact stellar objects called pulsars. Here's how they fit together. **by Victoria M. Kaspi**

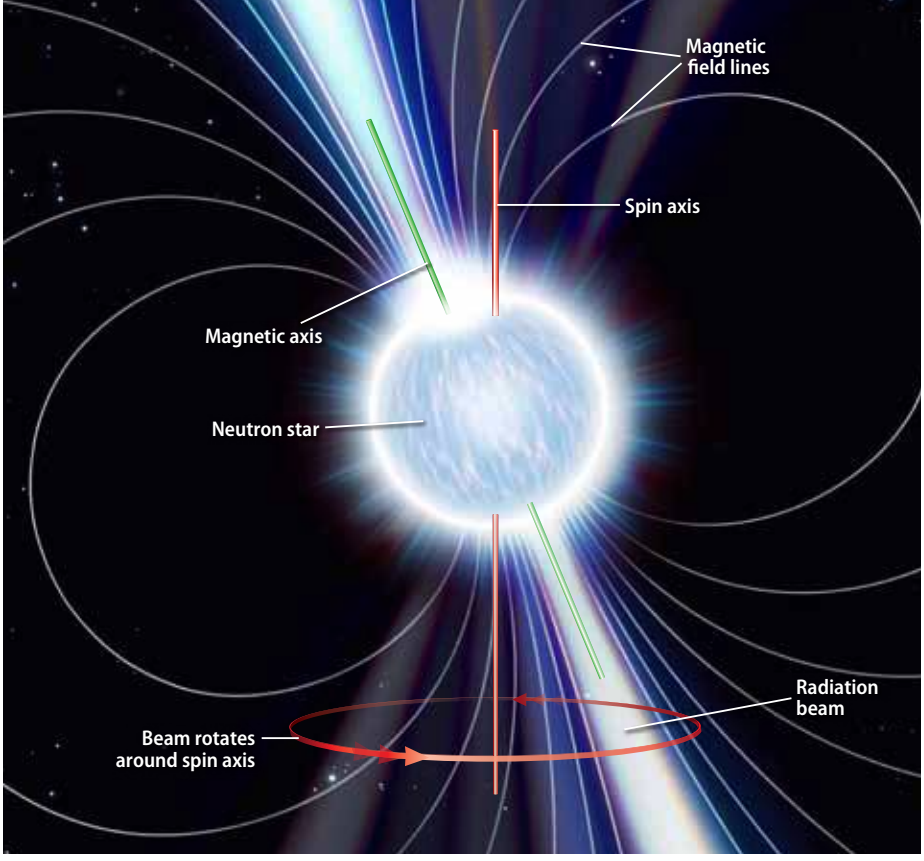
If you browse through an astronomy book published 25 years ago, you'd likely assume that astronomers understood extremely dense objects called neutron stars fairly well. The spectacular Crab Nebula's central body has been a "poster child" for these objects for years. This specific neutron star is a pulsar that rotates roughly 30 times per second, emitting regular apparent pulsations in Earth's direction through a sort of "lighthouse" effect as the star rotates.

While these textbook descriptions aren't incorrect, research over roughly the past decade has shown that the picture they portray is fundamentally incomplete. Astronomers know that the simple scenario where neutron stars are all born "Crab-like" is not true. Experts in the field could not have imagined the variety of neutron stars they've recently observed. We've found that bizarre objects represent a significant fraction of the neutron star population. With names like magnetars, anomalous X-ray pulsars, soft gamma repeaters, rotating radio transients, and compact central objects, these bodies bear properties radically different from those of the Crab pulsar. Just how large a fraction they represent is still hotly debated, but it's at least 10 percent and maybe even the majority. That the bulk of neutron stars may be peculiar objects that were unimaginable just a decade ago is one of the most startling recent discoveries in astrophysics. It's time to rewrite the textbooks.

SAR menagerie

Long the pulsar poster child, the Crab Nebula's central object is a fast-spinning neutron star that emits jets of radiation at its magnetic axis. Astronomers detect the radio signature from these jets as pulses. It turns out that scientists are finding other classes of pulsars that don't appear to share traits with the Crab's central object.

Don Dixon for *Astronomy*



Radiation beams emanate from a radio pulsar's magnetic axis, which is misaligned from the star's spin axis. As the object rotates, the beams flash the observer and appear as pulses. *Astronomy*: Roen Kelly

Surveying neutron stars

To properly describe the neutron star population as we understand it is to visit a wild and wonderful "zoo" of objects. Each seems intent on proving itself the most exotic of the lot — not that they need to try that hard.

All neutron stars share some common, bizarre properties. Having masses upward of half a million Earths crammed into a sphere some 12 miles (20 kilometers) wide, these objects are the second most compact known in the universe — after black holes. At a neutron star's center, the density is at least 10 times that within the atomic nucleus; we don't understand the laws of nature within densities this high.

Even more impressive are neutron stars' rapid rotation rates — astronomers know of at least one that completes more than 700 spins per second. Despite the tremendous gravitational pull at their surfaces, neutron stars rotating at these rates are almost certainly slightly pancake-shaped due to the rotation. (On a typical neutron star, you'd be "pulling" a few trillion Gs, if tidal forces hadn't already shredded you or radiation hadn't zapped you to oblivion.) An open question is just how fast one of these objects can spin without flying apart.

What's in the zoo?

Naïvely, one might think that by being a close cousin of the black hole, a neutron star should not have much "hair" — that is, details. Figuratively speaking, however, researchers now realize that neutron stars are awfully complicated. The variety of properties among the different classes is genuinely astonishing.

We've known about the classic young "radio pulsars" since University of Cambridge graduate student Jocelyn Bell discovered the first such object in 1967. Originally, her research group thought the regular radio pulsations were signals from aliens — such consistent signals were unprecedented in astronomy. Today, we understand that these signals are from rotation-powered pulsars (RPPs): rapidly rotating, highly magnetized neutron stars that produce narrow beams of radiation emanating from their magnetic poles, with the magnetic axis misaligned from the spin axis. This beaming property makes radio pulsars the "lighthouses of the cosmos." The beamed radiation spans the electromagnetic spectrum, although it generally is most easily observed with radio telescopes. Astronomers know of nearly 2,000 radio pulsars in the Milky Way, most of which inhabit the disk.

Neutron stars, and thus pulsars, are born in supernova explosions. As the slowly rotating progenitor star collapses, physics insists on the conservation of angular momentum — a constraint shared with figure skaters during spectacular spinning stunts. Thus some neutron stars start life spinning rapidly (on average rotating roughly 50 to 100 times per second).

A classic radio pulsar's impressively strong magnetic field acts to "brake" the star — it emits radiation as any rotating magnet must. Such magnetic fields are enormous, on the order of 10^{12} gauss — more than a trillion times as strong as Earth's magnetic field and too high for scientists to reproduce in a terrestrial laboratory. Astronomers infer such fields from the fact that these stars' rotation rates are slowly decreasing — in other words, they are "spinning down."

At a neutron star's center, the density is at least 10 times that within the atomic nucleus; we don't understand the laws of nature within densities this high.

The Crab Nebula's radio pulsar powers the surrounding nebula with its intensely magnetized "wind" of highly energetic particles. The pulsar's ambient magnetic field accelerates electrons and positrons, which causes the ghostly white glow within the thermal filamentary remains of the exploded progenitor star. Astronomers detect "pulsar wind nebulae" only in the most powerful pulsars. These nebulae can have dramatic and sometimes puzzling morphologies. For

Victoria M. Kaspi, *a professor of physics at McGill University in Montreal, Canada, is a pulsar and neutron star expert.*

example, the 150-millisecond pulsar PSR B1509–58 powers the X-ray nebula dubbed the "Hand of God." This huge nebula has fingers of energized material emanating from the central region, which holds the pulsar.

Astronomers recently discovered a likely subclass of radio pulsars called rotating radio transients (RRATs). Unlike classical radio pulsars, these objects seem to emit radio waves intermittently and in short bursts, such that we don't detect a regular pulsation. Why these objects are seemingly incapable of producing consistent regular signals is a mystery. Careful study of the RRAT bursts has revealed that they in fact occur at time intervals that are specific multiples of an underlying periodicity, supporting the idea that such objects are an extreme form of radio pulsar.

While researchers know of only about one dozen RRATs, they easily could have missed a huge population of these objects because of the way sky surveys have looked for radio pulsars. Some astronomers think RRATs could outnumber classical radio pulsars. Modern radio pulsar investigations, such as the Pulsar-ALFA survey currently underway at the 305-meter radio telescope in Arecibo, Puerto Rico, routinely use special software to look for isolated single bursts — the RRAT signature.

NASA/CXC/SAO/F. Seward et al.

The Crab Nebula's pulsar was one of the first discovered. This radio pulsar's fast rotation rate (about 30 spins per second), combined with a strong magnetic field, generates an intense wind that energizes the surrounding material.

Young pulsar PSR B1509–58 emits enough energy to light up this massive nebula dubbed the "Hand of God." The nebula spans some 150 light-years. The neutron star is in the "hand's" center, with finger-like structures energizing knots of material in a neighboring gas cloud. Blue represents the most energetic X-rays and red the least. Gas clouds emitting radio waves show up as purple. NASA/CXC/SAO/P. Slane et al.

In isolation

Astronomers had long thought radio emission was the hallmark of neutron stars. But several different subclasses of radio-quiet neutron stars have emerged as attention grabbers in the past decade.

The so-called isolated neutron stars (INSs) are rather poorly named given that the vast majority of radio pulsars are also isolated but not classified as INSs. Researchers have confirmed that there are seven INSs, in addition to one candidate object.

These bodies' defining properties are that they are relatively close to us, have X-ray emission with relatively low X-ray luminosity, and have only a visible-light counterpart. Those INSs known are within roughly 1,600 light-years of Earth; beyond that, they're likely too faint for current detectors. They also have relatively long periods as measured with X-ray telescopes, ranging from 3 to 11 seconds. They emit copious X-rays because they are hot due to the decay of a previously intense magnetic field.

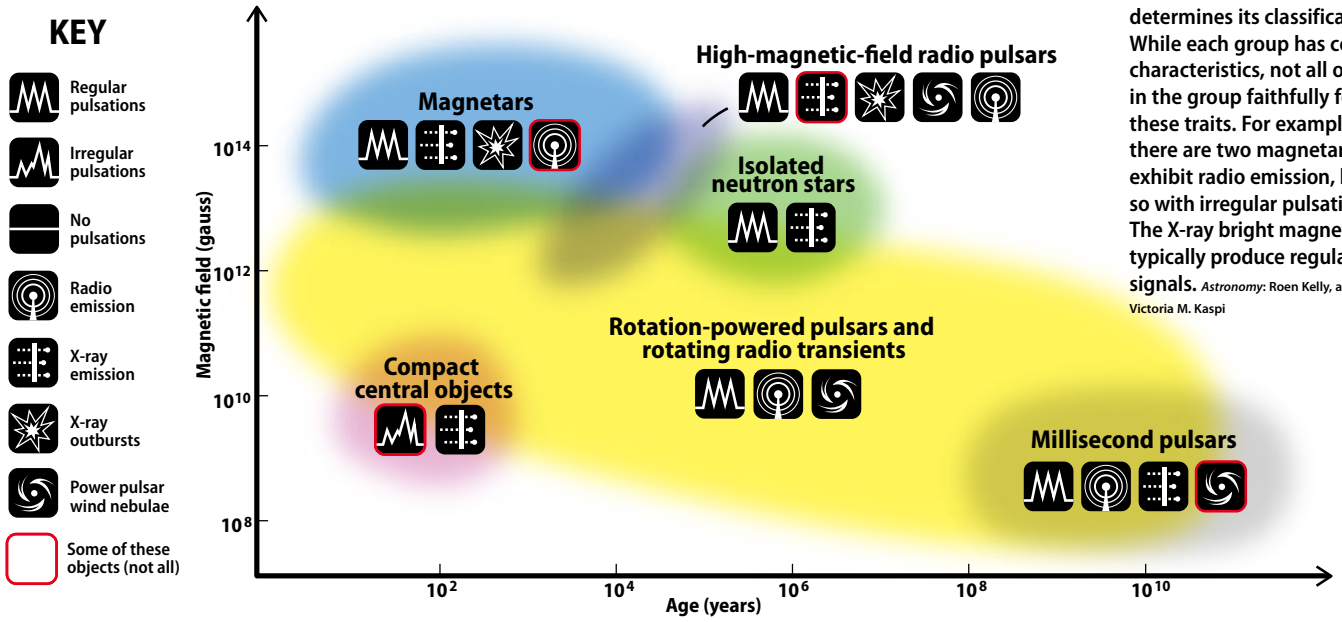
Surprisingly, the typical INS has a magnetic field that is somewhat stronger than that of the typical radio pulsar. (The reason for this is unclear, although one theory posits that INSs are regular radio pulsars viewed off-beam so that they appear radio quiet.)

The Arecibo Observatory in Puerto Rico is an important tool for finding pulsars. Astronomers use this 1,000-foot-wide (305 meters) radio telescope to scan the skies to locate more of these compact objects. Photo courtesy of the NAIC - Arecibo Observatory, a facility of the NSF

Extreme magnets

Then there are magnetars, the "bad boys" of the neutron star population (a description first suggested by my good friend and colleague Maxim Lyutikov of Purdue University). Magnetars are the most spectacular of the group, emitting enormous outbursts of X-rays and gamma rays. At their "baddest," magnetars can

The lives of pulsars



A pulsar's magnetic field at birth and its age when astronomers observe it likely determines its classification. While each group has certain characteristics, not all objects in the group faithfully follow these traits. For example, there are two magnetars that exhibit radio emission, but do so with irregular pulsations. The X-ray bright magnetars typically produce regular signals. *Astronomy:* Roen Kelly, after Victoria M. Kaspi

briefly outshine all other cosmic gamma-ray sources combined, which, coming from an object only 12 miles (20 km) wide, is impressive. A magnetar's giant flare can release in a matter of seconds as much energy as the Sun produces in thousands of years.

Magnetars appear to come in two flavors: soft gamma repeaters (SGRs) and anomalous X-ray pulsars. The SGRs seem to be the more active of the two classes, exhibiting more frequent and larger bursts. However, some recently detected magnetars have demonstrated properties common to both groups at different times, suggesting either an evolutionary relationship between classes or a continuum of behaviors. Magnetars show relatively long X-ray pulsations, even when not undergoing huge outbursts. Their rapid rates of spin-down imply that magnetars have the highest known magnetic fields in the universe, upward of 10^{14} or even 10^{15} gauss — that's 100 to 1,000 times greater than regular radio pulsars.

Astronomers think magnetars' massive pyrotechnic displays result from crust breaking — a sort of star quake — caused by stress induced by the enormous internal magnetic field. Theory says that at these field strengths, currents within the star dissipate relatively rapidly, resulting in spontaneous magnetic field decay. ("Rapidly" means the field decays on a timescale of only a few tens of thousands of years, unlike in regular radio pulsars, where the fields could be stable for billions of years.) In one theory, INSs started out as magnetars; these extreme magnets would possess the sort of magnetic fields required to result in INS-strength fields much later in life.

At the center

Any census of the neutron star zoo wouldn't be complete without mention of the handful of "compact central objects" (CCOs), so-named because they're located in the centers of supernova remnants. The poster-child CCO is the central object in the young, oxygen-rich supernova remnant Cassiopeia A. Astronomers have studied this mysterious compact object for about 10 years, most often with the Chandra X-ray Observatory. Particularly puzzling is the CCO's lack of X-ray pulsations.

We now classify three other previously mysterious CCOs as pulsars. Astronomers have shown that the CCOs at the centers of supernova remnants Puppis A, Kes 79, and PKS 1209–52 pulsate in X-rays, but with very low rotation slowdown rates. This implies far smaller magnetic fields than those of typical young radio pulsars. These surprisingly low magnetic fields inspired some researchers to dub them "anti-magnetars," a term that is still somewhat controversial and not universally adopted. One possibility is that these objects emit copious X-rays because they're still quite warm — remnants of the intense heat in their formation in supernova explosions. The neutron star was born spinning relatively slowly and with a low magnetic field.

A magnetar's giant flare can release in a matter of seconds as much energy as the Sun produces in thousands of years.

A neutron star metamorphosis

Recent observations have revealed a connection between high-magnetic-field radio pulsars and magnetars. Astronomers know of seven radio pulsars that have spin-down inferred magnetic fields either extremely close to or higher than bona fide magnetars. My research group has spent years looking for magnetar-like X-ray emission from high-magnetic-field radio pulsars. In these sources, the magnetic field seems high enough that it ought to cause some stress or internal heating with an observational signature similar to that seen in magnetars. However, these

high-magnetic-field radio pulsars tend to be much fainter than typical magnetars, a puzzling result that keeps me up at night.

My insomnia was recently given some relief: In 2006, NASA's Rossi X-ray Timing Explorer detected a sudden, few-week X-ray outburst from the well-established, young, high-magnetic-field radio pulsar PSR J1846–0258 located in the supernova remnant Kes 75. Our team, led by my former student Fotis Gavriil, now at NASA's Goddard Space Flight Center, had been monitoring this source patiently since 1999 with no sign of activity. Why the object mysteriously chose 2006 as the year to reveal magnetar properties is a mystery. My student Margaret Livingstone and postdoctoral associate Stephen Ng have used recent X-ray observations to show that the pulsar is more-or-less back to its mild-mannered self, albeit with a few subtle yet intriguing changes. PSR J1846–0258 revealed an interesting Jekyll and Hyde routine.

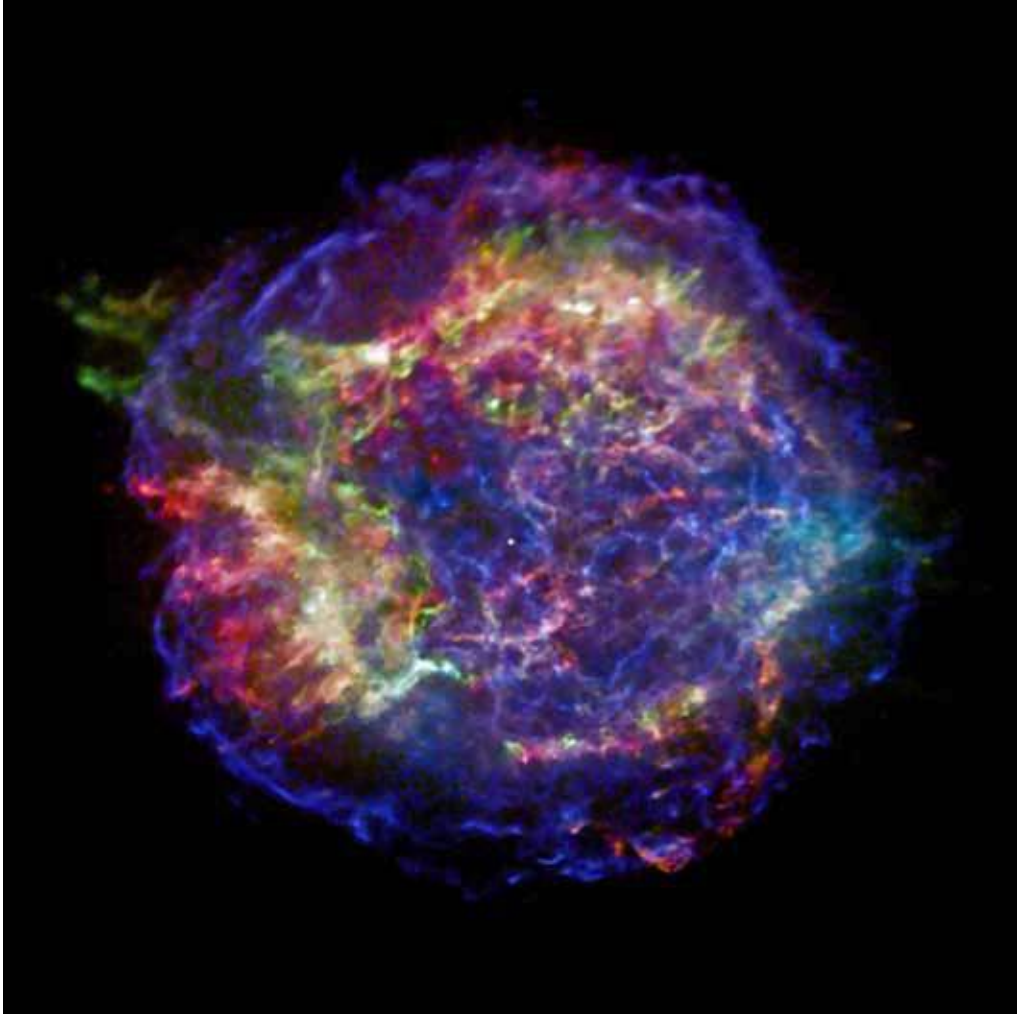
Where young neutron stars fit

The challenge of the past decade continues today: to find a way to unify the surprising diversity of neutron star behaviors into a coherent picture. Interesting ideas are emerging. Astrophysicist José Pons, of Universitat d'Alacant in Spain, and collaborators have recently shown that thermal evolution and magnetic field decay are inseparable in detailed models of neutron star cooling. Temperature affects the electrical resistivity of the star's crust, which in turn affects how the magnetic field evolves. At the same time, the field's decay can produce heat that then affects how temperature evolves.

In this model, neutron stars born with large magnetic fields undergo significant field decay, which keeps them hotter longer. The theory says that magnetars are the highest magnetic field sources, which is consistent with what astronomers observe. The model also explains the puzzling fact that INSs, despite their proximity, all appear to have high magnetic fields relative to the RPP population. The most magnetized sources will remain hottest — hence most easily observed — for longest.

If this unification picture is correct, radio pulsars (and their RRAT subclass), INSs, and magnetars have such disparate properties simply because of their different magnetic fields at birth combined with their present ages. The scarcely magnetized CCOs fit in as the neutron stars with the lowest magnetic field at birth; they are X-ray hot only because of their young age. High-magnetic-field radio pulsars seem to be a crossroads class. See "The lives of pulsars" on page 48.

There is no shortage of ideas for future tests of Pons' theory of neutron star "grand unification." Deep X-ray observations of high-magnetic-field radio pulsars can determine their characteristic light signatures (called spectra) and fluxes; shallow X-ray observations will monitor and search for magnetar-like variations. Catching magnetars in outburst will constrain models of these magnets and help astronomers understand crucial parameters like outburst recurrence rate, which is central to understanding how many magnetars the galaxy contains. Systematic timing and spectral studies of newly discovered members of any of the classes will progress the field, given how few RRATs, INSs, CCOs, and magnetars are known. Clearly, neutron star astronomers have their work cut out for them.



▲ **Cassiopeia A** is a supernova remnant that holds a compact object at its center. This young, central neutron star emits faint X-rays. NASA/CXC/SAO/D. Patnaude et al.

▶ **Supernova remnant Kes 75** holds a peculiar pulsar — its magnetic field is more powerful than those of most pulsars, but not as strong as those of magnetars. For a few weeks in 2006, this object underwent sudden X-ray outbursts energetic enough to rival bona fide magnetars. Scientists are working to understand how this object fits into regular radio pulsars and the more extreme magnetars. NASA/CXC/GSFC/F. P. Gavriil et al.

Visit www.Astronomy.com/toc for more about magnetars.

Ask Astro

Astronomy's experts from around the globe answer your cosmic questions.

Our Sun's finale

Q: Billions of years from now, what will be the fate of our Sun? Would it be a hard surface we could walk on? — **Rich Livitski,** Norwalk, California

A: The fate of the Sun — and of Earth — will result from two unavoidable processes: element fusion that provides the Sun's luminosity and the loss of mass from its surface.

Right now, the Sun fuses hydrogen nuclei into helium nuclei. The mass of four hydrogen atoms is slightly more than one helium atom, and the difference, which is related to energy by Albert Einstein's famous equation $E=mc^2$, lets the Sun shine. When the central 10 percent of the Sun has no more hydrogen — which will happen in about 5 billion years — this core will shrink, the hydrogen fusion will move to a shell surrounding the core, and the Sun will expand to many times its present size. The core will continue to get its energy from hydrogen fusion until about half its mass is helium. Then, quite suddenly, it will switch to fusing helium, creating carbon and oxygen. When the helium has all been converted to carbon or oxygen, the Sun's core will go back to fusing hydrogen in a shell until the second process — mass loss — kicks in.

The mass loss epoch starts when the Sun's luminosity reaches several thousand times what it is today. The star will become unstable and start to pulsate. It will shrink and grow and shrink and grow within a period of about a year, becoming a Mira variable. This pulsation will produce waves in the Sun's atmosphere and lead to the loss of mass. **When all that is left is the carbon-oxygen core — which is extremely small and dense (a teaspoonful would weigh a ton) — we would call the Sun, ultimately, a white dwarf.**

A Sun-like star ends up as a carbon-oxygen white dwarf (center), the leftover core of its former self. In the late stages, the star pulsates and loses its atmosphere, usually in brilliant fashion, forming a planetary nebula. The Cat's Eye Nebula, shown here, is one of the most complex planetary nebula structures. NASA/ESA/HEIC/and The Hubble Heritage Team (STScI/AURA)

I wouldn't recommend trying to walk on one of these objects, however. First, they are all still pretty hot — the oldest ones have only cooled to about 5800° Fahrenheit (3500 kelvin) over the age of the universe, and it would take at least 250 billion years to cool to 170° F (350 K). Second, the immense gravity would squash you flat. Third, you would sink in. Fourth, as you approached the white dwarf, the tidal force would pull you apart. All bad news for visiting a white dwarf! — **Lee Anne Willson,** Iowa State University, Ames

AVOIDING COLLISIONS

Q: When we send spacecraft to the outer gaseous planets, how do they survive the trip through the asteroid belt between Mars and Jupiter? — **Dave Duryea,** Bartonville, Illinois

A: An asteroid is generally a rocky object orbiting the Sun, defined as smaller than a planet and larger than a meteoroid. Most are located in the "main belt" between Mars and Jupiter. A meteoroid is often defined as smaller than an asteroid and larger than a grain of sand, typically millimeters to meters in size. Micrometeoroids are smaller than meteoroids (usually smaller than a millimeter). When a spacecraft flies through the main belt on its way to Jupiter and beyond, it is theoretically exposed to threats from all of these space objects, but the specific concern involves only a narrow range of particle sizes.

The largest asteroid is Ceres, with a diameter of 605 miles (974 kilometers), but most asteroids are much smaller. If all asteroids could be combined into a single body, the resulting object's diameter would be somewhat less than half that of the Moon, making its volume less than 10 percent that of the Moon. However, there are far more small asteroids than the few larger ones. If you compare two sizes of asteroids (one a factor of 10 smaller in diameter), there would be 1,000 times as many of the smaller size. As the volume of the main belt region is vast (some trillion trillion cubic kilometers), the chances are remote of ever running into an asteroid the size of a car — or even the size of a baseball. So it is only the smallest particles we ever have to worry about, as they exist in significantly larger numbers.

When we design our spacecraft, we cover the outside metal structure

with thermal blankets composed of many layers of Mylar. The layers are spaced in such a way as to break up, and even vaporize, most of the high-speed particles smaller than about half a millimeter, so our key electronics and various propellant tanks are not harmed. Particles a bit larger than half a millimeter could still hit our spacecraft, but we rarely worry about particles larger than, say, a marble, as the chances are very low of ever running into one of them.

In that critical size range of half a millimeter to a few millimeters, we calculate an annual risk of a serious hit to be about 1 percent. This is generally true regardless of whether we are within or outside the main asteroid belt. The number of particles that pass through a specific area in a certain amount of time, however, decline somewhat as we travel farther from the Sun, rising only when passing near the gravitational fields of other planets. We accept this balanced level of risk, as the rest of the spacecraft reliability from design flaws or electronic failures is about that same level. Further, none of the eight NASA spacecraft that have crossed the main belt region has experienced a hit.

— Charles Kohlhase, Jet Propulsion Laboratory consultant

NEVER ASK ITS AGE

Q: How do astronomers make generalizations about the ages of stars, galaxies, and other celestial objects? — Jim McElwain, Kansas City, Missouri

A: Ages are among the most sought-after of astronomical numbers. The pinnacle is the age of the universe, which astronomers have found to be 13.7 billion years using both the universe's expansion rate and fluctuations in the cosmic microwave background. But what about the things in it?

From precise radioactive dating methods, the oldest things we can find in the solar system are primitive stony meteorites. They date to 4.6 billion years. Because everything in our solar system was formed together, that must also be the age of Earth and the Sun.

Find out what forces maintain Earth's axial spin or that of any other celestial body at www.Astronomy.com/toc.

Globular clusters typically contain a galaxy's oldest objects. By finding the ages of those stars, astronomers can pinpoint the galaxy's age. Astronomers estimate the stars in M15, pictured here, are about 12 billion years old. NASA/The Hubble Heritage Team (STScI/AURA)

We determine stars' ages in a variety of ways. Internal fusion powers stars. **As they mature and use up their fuel supplies, stars change both their internal and external structures. Theory then suggests how old they are. Stellar vibrations, which allow astronomers to examine stellar interiors, work as well.** Sun-like stars destroy their lithium by cycling it downward toward the core through convection; the lithium abundance tells their age. Because Sun-like stars also brake their spins through their winds and magnetic fields, we can use rotation rates. When we apply this method to observations of the Sun, we get ages consistent with what meteorites show.

Just as we do for the solar system, to find the ages of galaxies we look for their oldest objects — the stars in globular clusters. Those in our galaxy's halo date to 12 to 13 billion years old and thus affirm a rough age of the universe.

— Jim Kaler, University of Illinois, Urbana-Champaign

MAKING WAVES

Q: What are gravitational waves, and what do they have to do with the Big Bang? Can scientists detect them? — Akshata Doddamani, via www.Astronomy.com newsletter

A: Gravitational waves are fluctuations of space-time caused by masses in motion. Although Albert Einstein first predicted their existence in 1916, we have not yet detected them due to their extremely weak interaction with matter. This weak interaction makes gravitational waves powerful probes of the universe — they propagate to us largely as they were as early as 10^{-24} second after the Big Bang. In contrast, the earliest detectable electromagnetic radiation (called the cosmic microwave background [CMB]) originates from 380,000 years after the Big Bang, when the universe first allowed light to disperse.

Models of the Big Bang and inflation (a brief period of hyperexpansion) predict that the dynamics of the expanding universe generated primordial gravitational waves. Fortunately, scientists have several prospects for detecting them. Satellites such as the European Space Agency's Planck will measure the possible imprint the gravitational waves left in the CMB's polarization. Gravitational waves could slightly alter the arrival times of the signals from compact stars called pulsars. Ground-based detectors (such as the Laser Interferometer Gravitational-wave Observatory, and Virgo) and the planned Laser Interferometer Space Antenna (LISA) may detect a background of cosmological gravitational waves under optimistic assumptions. The proposed Big Bang Observer, a successor to LISA, is designed to detect them — an exciting prospect that will challenge our understanding of the universe. **— Deirdre Shoemaker,** Georgia Institute of Technology, Atlanta

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187**. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

10 top autumn binocular treats

All you need to enjoy these seasonal targets is a dark sky and good binoculars.

by Phil Harrington

With the nights getting longer and the air so crisp and clear, autumn is a great season for stargazing. The Andromeda Galaxy, the Double Cluster, and fabulous globular clusters M2 and M15 really get observers' blood flowing. This month, I continue my seasonal tour of the binocular universe that began in the May issue. Here are 10 of my favorite autumn targets.

Awash with stars

As her majesty Cassiopeia the Queen reigns near the zenith, she offers several deep-sky subjects for our binoculars. Among the best is open cluster **NGC 7789**. It lies about 3° southwest of Caph (Beta [β] Cassiopeiae) at the western tip of the constellation's W asterism. The faint mist of blurred starlight that you'll see through binoculars is the combined glow of the cluster's 1,000 dim stars.

Our first Messier object

M52 is another attractive Cassiopeia cluster. To find it, look 6° northwest of Caph. More than 200 stars form M52, but only a few are bright enough for binoculars to resolve. As you strain to see those faint points, consider that their light left the cluster more than 5,000 years ago.

A cluster to hoot about

The **Owl Cluster** (NGC 457) is the most fascinating open cluster in Cassiopeia. Lying about 9,000 light-years away, more than 80 stars call this cluster home. Several are visible through 10x binoculars. But what's especially fun about NGC 457 is its distinctive shape. *Astronomy* Editor David J. Eicher gave NGC 457 its common name in 1977.

About a dozen stars between 9th and 11th magnitude form the bird's body, while a pair of 10th-magnitude suns marks the tail feathers. Two arcs, each containing about half a dozen suns, outline the wings. The owl's dazzling eyes are magnitude 5.0 Phi (ϕ) Cassiopeiae and magnitude 7.0 HD 7902. Neither belongs to this open cluster, however. Instead, they lie in the foreground.

The Owl Cluster (NGC 457) in Cassiopeia is a naked-eye object from a dark site. The cluster looks great through binoculars. The bright stars forming the owl's eyes are foreground stars. Bob and Janice Fera

Two for the price of one

Found just across Cassiopeia's border with Perseus, the **Double Cluster** (NGC 869 and NGC 884) is a preeminent target for binoculars. Even when viewed from suburban backyards, each cluster resolves through 7x binoculars into a tight knot of white stars against a star-strewn backdrop. Through higher-power giant binoculars, the view overflows, which also brings out the many red supergiant stars scattered across the region.

X marks the spot

Follow an arc of stars about half a binocular field of view north of the Double Cluster to a clump of faint stars that forms the letter X. That's **Stock 2**, a little-known open cluster that stands out remarkably well through binoculars despite its crowded surroundings. Stock 2 is also known as the Muscleman Cluster because its stars resemble a headless stick figure flexing his muscles. His legs stretch out in two straight lines to the east, while his flexing arms curve to the west, above his long, headless neck.

Brilliant and easy

The **Alpha Persei Association**, also known as Melotte 20, is one of the sky's true binocular gems. Many dazzling blue-

Pat and Chris Lee/Adam Block/NOAO/AURA/NSF

Globular cluster M2 shines at magnitude 6.6 in the northern part of Aquarius. This object is one of the sky's richest and most compact globulars.

white "diamonds" scatter throughout the area in small bunches, with magnitude 1.8 Mirfak (Alpha [α] Persei) the brightest of the horde. While most of the stars appear white or blue-white, a few show subtle tinges of yellow or orange. Studies show that the association's stars are only about 51 million years old, younger than many of Earth's diamonds.

The great galaxy

Binoculars show the **Andromeda Galaxy** (M31) as a broad oval smudge of grayish light that may appear dull and featureless at first. It lies 1.3° west of magnitude 4.5 Nu (ν) Andromedae. Close inspection reveals that the galaxy extends from the northeast to the southwest for an incredible 3° — the same as six Full Moons stacked end to end. Giant binoculars will add a lane of dark nebulosity along the galaxy's edge. And be sure to look for Andromeda's satellite elliptical galaxies, M32 and NGC 205.

Hazy luster

Look 4.8° south-southwest of magnitude 2.1 Almach (Gamma [γ] Andromedae) for open cluster **NGC 752**, one of the season's largest and, at magnitude 5.7, brightest. It's visible without optical aid from a dark site. Binoculars expose an irregular haze created from the amassed light of the cluster's 60-some stars. Binoculars of 15x and higher magnification reveal several fainter suns that appear chain-linked across the cluster.

Southern ball of suns

M2 may be one of autumn's brightest globular clusters, but finding it among the faint stars of Aquarius can be a problem. Begin at the Water Jar asterism of four stars just to the east of Sadalmelik (Alpha Aquarii). The Water Jar and the star form a westward-pointing arrow that leads directly to M2, which lies 8° west of Sadalmelik. Look there and you will see M2 as a fuzzy "star." Binoculars magnifying 16x or more will show that M2 is not round, but slightly oval.

Near the Great Square

Globular cluster **M15** is easy to spot 4.2° west-northwest of Enif (Epsilon [ε] Pegasi), the star marking the nose of Pegasus the Flying Horse. A 6th-magnitude sun just to the cluster's east creates the illusion of a double star through binoculars. Look carefully: M15 is the fuzzy one, even at low power. Most binoculars reveal it as a misty patch absent of stars, but with a brighter core.

Have another favorite autumn object? Post your observations in the Binocular forum on www.Astronomy.com/forums. And until next time, remember that two eyes are better than one.

See images of all these objects at www.Astronomy.com/toc.

Phil Harrington *is an* Astronomy *contributing editor. His new book,* Cosmic Challenge*, will be published this fall by Cambridge University Press.*

Astrophotography: part one

How to pick a camera for astroimaging

Sky-shooting has never been easier. Stunning results may be just a click away with off-the-shelf digital SLRs. **by Michael A. Covington**

Once upon a time, photographers who wanted to capture the sky used the same basic equipment for everything: a 35mm film single-lens reflex (SLR) camera. What it did well, we did well. What it did poorly, we did poorly. But those days are no more. Today, amateur astroimagers have a wide range of imaging devices to choose from. Each has its strengths and weaknesses.

Camera basics

All modern cameras use electronic image sensors. It no longer matters whether the sensor is CCD (charge-coupled device) or CMOS (complementary metal-oxide semiconductor); after years of competition, the two technologies perform much alike. Either way, you get an array of tiny photocells, called pixels, and the circuitry to control the exposure and read out the image. The number of pixels can range from 640×480 for tiny planet images to millions of pixels (megapixels) for star-studded deep-sky shots.

Some sensors produce color images while others are monochrome. The color sensors use a "Bayer matrix" (pronounced BY-er), in which alternate pixels are filtered red, green, and blue. A computer interpolates the information to smooth the image. Monochrome sensors yield sharper images, but creating color photos becomes more awkward — you have to take red, green, and blue exposures through separate filters and then combine them in a computer.

You should ask yourself two more practical questions before choosing a camera: Can you use it for daytime photography, and can you use it for astroimaging without connecting a computer? The answer to both questions is "yes" for digital single-lens reflex (DSLR) cameras and "no" for most other astrocameras.

DSLR cameras

Manufacturers build DSLR cameras like film SLRs. Both have a mirror, a focusing screen, and a viewfinder that lets you view and focus through the lens optically whether the camera is turned on or not. DSLRs are cost-effective and easy to use, and you can take daytime photos with them. They work well for deep-sky imaging — especially for wide-field shots when the camera "piggybacks" on a telescope — and are ideal for full-face shots of the Moon, the Sun, and lunar and solar eclipses. What I like most about DSLRs is that I don't have to bring a computer along, although you can computer-control a DSLR if you prefer.

Choose a DSLR carefully because you'll have to live with it a long time — you can't simply change brands of film. For instance, many Nikon cameras have a built-in noise removal algorithm that

Canon's Digital Rebel introduced many astrophotographers to the wonders of digital imaging. Canon U.S.A.

A cutaway view shows the inner workings of an early Digital Rebel. The EOS 350D (Digital Rebel XT) model came out in early 2005. Canon U.S.A.

The North America Nebula (NGC 7000) stands out amid a panorama of star clouds in the northern Milky Way. The author took this photo with a Canon Digital Rebel and Sigma 105mm lens at f/4.5, piggybacked on an 8-inch SCT. Michael A. Covington

tends to "eat" tiny star images, and you can't turn it off. Many DSLR brands have controls that astroimagers will find hard to use, with too many buttons to press or, conversely, lacking a button that does what you need.

For these and other reasons, many astroimagers prefer Canon EOS DSLRs. Canons produce good astronomical images and have controls well suited for the job. Canon has shown a continuing commitment to astronomy. At one time, they even made a special astronomical DSLR, the EOS 20Da, and their later EOS 40D and 50D models have features requested by astroimagers. Thanks to the compact size of the camera body, Canon EOS cameras also can accept Nikon, Pentax, and other lenses using adapters.

Longtime astrophotographer **Michael A. Covington** *is senior research scientist and associate director of the Institute for Artificial Intelligence at the University of Georgia.*

If you're deeply into Nikon gear, you might also consider Fuji DSLRs, which are built around Nikon bodies but optimized for scientific photography.

What DSLR features do you need? You'll want a camera with live focusing ("Live View" in Canon-speak). This means you can focus by viewing, on the camera's display screen, a greatly enlarged portion of the image actually falling on the sensor. It's by far the best way to focus on stars. (Autofocus is useless; an autofocuser can't even see stars most of the time.) And on many DSLRs, live focusing lets you start an exposure electronically, which means no shutter movement and thus no vibration.

Vital DSLR accessories include a cable release (preferably one with a built-in timer) and spare batteries. Batteries run down quickly on chilly nights; keep the spares in your pocket so they'll stay warm.

Don't get hung up on a huge number of megapixels or a large sensor. Extra megapixels don't necessarily help. Fewer pixels will be larger, more sensitive to light, and less subject to noise caused by stray electrons. And there is nothing sacrosanct about a "full-size" sensor that matches a 35mm film frame. In fact, such sensors are bigger than an eyepiece tube, and the more common 15x22mm sensor actually fits telescopes better.

If you want to photograph emission nebulae, you should know that DSLRs do not record deep-red light well. And such nebulae emit much of their radiation in the deep red, at a wavelength of 656 nanometers. Inherently, DSLR sensors are sensitive to red light, but manufacturers include an infrared-blocking filter so that daytime color photographs look realistic. Serious astroimagers often pay to have this filter replaced with one that transmits deep-red light. Because this modification makes the camera less suited for daytime photography and it only affects hydrogen nebulae (not stars

Jupiter's banded atmosphere shows plenty of detail in this image, which the author took through an 8-inch SCT and a 3x Barlow. He recorded 2,000 video frames with a modified webcam, then aligned, stacked, and sharpened them with ***Registax***. Michael A. Covington

Live focusing lets you focus on an enlarged portion of the image that falls on the camera's CCD sensor. Nikolai Sorokin/Dreamstime.com

or galaxies), many astrophotographers, myself included, choose not to do it.

What about lenses? A zoom lens that typically comes with a camera is generally too slow because of its small aperture and not sharp enough for astroimaging. Instead, consider a 50mm f/1.8 lens, the lens that was standard on film SLRs. Such lenses are sharp, fast, and inexpensive.

If you plan to try piggybacking, you'll also want other non-zoom telephoto lenses. Better yet, get a lens mount adapter so you can use Nikon, Pentax, Zeiss, or another telephoto lens on your Canon DSLR. Don't worry about being unable to autofocus through an adapter because you should always manually focus astroimages anyway.

Astronomical CCD cameras

Cooled CCD astrocameras have long been a mainstay for serious deep-sky photographers, or at least for well-heeled amateurs, and those who work at observatories. Such cameras have come down in price to the point where manufacturers are mass-producing suitable sensors for DSLRs and high-end video equipment. Thermoelectric cooling reduces electronic noise, which lets you record fainter objects. Leading makers of these cameras include Apogee, SBIG, Meade, and Orion.

Using a CCD astrocamera requires connecting it to a computer and power source, so you'll need a laptop with suitable software and a red filter for the screen to preserve your dark adaption. Compared to a DSLR, images from a CCD astrocamera are better but require much more effort.

Video imagers

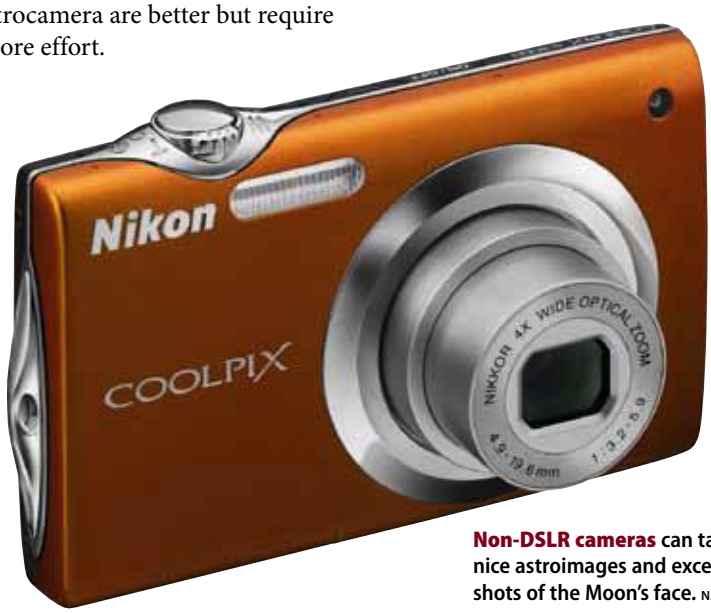
For imaging planets, you'll want an astronomical video camera. Let the camera record thousands of video frames and then have software select and combine the sharpest frames.

Video astronomy started with modified webcams. Amateurs simply took the lens off a cheap webcam and fit an eyepiece tube adapter in its place. Today, webcams have been replaced by the Meade Lunar and Planetary Imager, Orion planetary cameras, and higher-end cameras from Imaging Source, Lumenera, and others.

You can choose from color imagers (best for fast-rotating planets such as Jupiter) and monochrome cameras that require you to use a red-green-blue filter wheel to get color shots. A video astrocamera also can double as an autoguider to watch a star and transmit corrections to your telescope while you photograph deep-sky objects with a different camera. Like CCD astrocameras, astronomical video cameras require a connected computer. Some also will take still pictures up to a few minutes long, giving you a taste of deep-sky imaging.

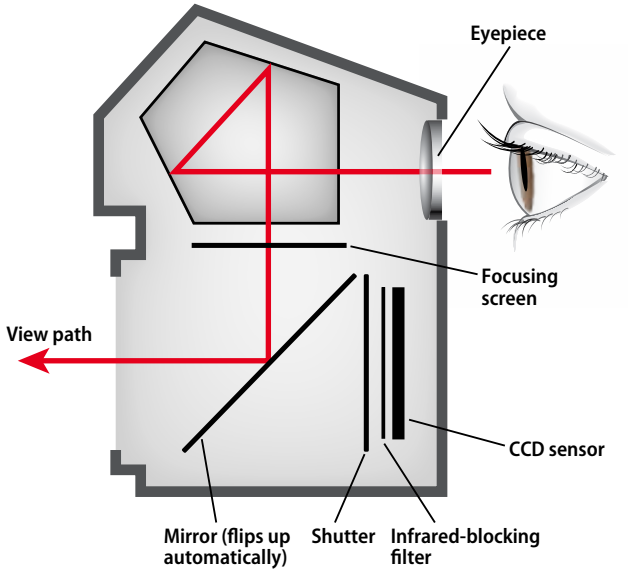
Non-DSLR digital cameras

Astroimagers shy away from typical point-and-shoot digital cameras. Even cameras with the same number of megapixels have smaller, less-sensitive sensors. Aimed directly into a telescope's eyepiece, however, they can capture nice images of the Moon's full face without the vibration from an SLR's mirror and shutter.



Non-DSLR cameras can take nice astroimages and excel at shots of the Moon's face. Nikon, Inc.

Canon's EOS 50D model, which came out in 2008, has many of the features astroimagers crave. It has become a favorite of those who like to capture the sky. Canon U.S.A.



The guts of a digital SLR are quite simple. A CCD sensor records light much like film. One difference is the infrared-blocking filter, which helps make daytime color photos look realistic. *Astronomy*: Roen Kelly, after Michael A. Covington

On the horizon are interchangeable-lens, DSLR-like cameras with no mirrors. They will rely entirely on electronic viewing screens. These "mirrorless DSLRs" may replace conventional DSLRs because they are lighter and produce less vibration.

The death of film?

It may surprise you to learn that film isn't dead. In fact, good film equipment has never been cheaper, and Kodak still makes and recently improved the best color films ever, Elite Chrome 100 and 200. Be forewarned that at the same ISO speed, film picks up less light in a 5-minute exposure than a DSLR does in 2 minutes. This is one reason digital sensors have taken over.

Although a film camera and lens may cost only $20, you'll spend another $20 to acquire and process each roll of film. Processing is still available from E-Six Lab in Atlanta (www.e-sixlab.com), and they'll scan your images to digital format so you can adjust and enhance them with Adobe *Photoshop*® just as if they had come from a DSLR. So, if you've always wanted to try film astrophotography, do it now. No one knows how much longer you'll be able to do so.

This is part one of Michael Covington's imaging series. He will look at camera-on-tripod imaging in a future issue.

A colorful Moon greeted observers of the October 27, 2004, total lunar eclipse. The author snapped this image with a Nikon Coolpix 990 compact digital camera mounted on a bracket and aimed into the 25mm eyepiece of a 5-inch f/10 telescope. Michael A. Covington

All about the Double Cluster

Two brilliant open clusters in Perseus hold dozens of stars younger than the Sun.
by Raymond Shubinski

The Double Cluster (NGC 869 and NGC 884) in Perseus is one of the most beautiful objects in the northern sky. Observers have seen this fuzzy patch of light since ancient times. Greek astronomer Hipparchus cataloged the object as early as 130 B.C. However, astronomers didn't discover the true nature of the Double Cluster until the invention of the telescope many centuries later.

This deep-sky object is actually two separate groupings of stars known as open, or galactic, clusters. Like the Beehive (M44) and the Pleiades (M45), mostly hot young stars make up NGC 869 and NGC 884. Open clusters typically contain hundreds to thousands of stars and sit in the Milky Way's disk.

A bit of a myth

Perseus is at the center of a mythological web of adventure and intrigue. Born the son of Zeus and the mortal Danaë, he was a demigod but not immortal. King Polydectes of Seriphos challenged Perseus to slay one of the Gorgons, whose gaze could turn an onlooking victim into stone. To give Perseus the upper hand, Athena, Hermes, and other gods gave him a helmet, winged sandals, a shiny shield, and a curved sword studded with jewels in its handle.

The rest of the story is well-known: Perseus beheaded Medusa, saved the beautiful Andromeda, and performed many other heroic deeds along the way. At last, the gods placed him among the stars, head of Medusa in one hand and the jeweled sword in the other.

The Double Cluster spans about 1° in Perseus' sword. NGC 869 (the cluster at the right) is the brighter of the two clusters, but NGC 884 contains a more varied color palette. Thomas V. Davis

This early photograph of the Double Cluster dates to around 1893. Isaac Roberts, a pioneer in astrophotography, took this image. Michael E. Bakich library

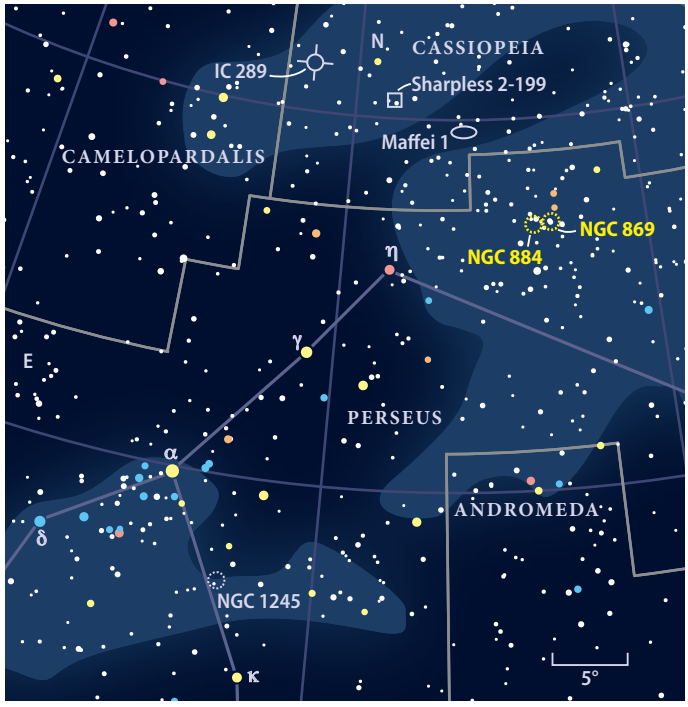
The Double Cluster marks the bejeweled handle of Perseus' magic sword. The object extends about 1° in the sky — the width of two Full Moons. Each cluster is about half that width. The trick is to separate the clusters to see each as distinct. These two NGC objects lie in the part of the Milky Way's plane that runs through Cassiopeia. Gauging the clusters' true magnitudes is a bit tricky because their light mingles with that of myriad faint stars. Sources list a wide range in magnitudes, from 3.5 for NGC 869 and 3.6 for NGC 884 to as faint as 5.3 and 6.1, respectively. The accepted apparent magnitude of the combined object is roughly 4.2.

Like counting the number of stars you can see on a truly dark night, seeing detail in the Double Cluster without optical aid is a challenge. As with a number of complex objects, modern observers sometimes make claims not found in ancient records. Some observers today say they can make out the stellar nature of this object without optical aid. Is this because they've seen images of the Double Cluster and know what they are looking for?

Raymond Shubinski *is a frequent* Astronomy *contributor. An experienced observer, he also enjoys astronomical history.*

Bill and Sally Fletcher

Perseus the Hero lies in dense star fields of the Milky Way's disk. However, you can still make out the shapes of the Double Cluster (NGC 869 and NGC 884). These twin clusters are in the northern region of the constellation.



Use this star chart to find the Double Cluster, which is about 8° west-northwest of Eta (η) Persei. The constellation of Perseus the Hero lies near Andromeda and Cassiopeia. *Astronomy*: Roen Kelly

A place in history

It seems odd that French comet-hunter Charles Messier didn't include the two clusters in his famous 18th-century catalog. He listed the Orion Nebula (M42), M44, and even M45, but not this marvel in Perseus. The German-born English astronomer William Herschel appears to have been the first, in the early 19th century, to recognize the object as separate clusters.

Nineteenth-century astronomers were ebullient over the Double Cluster. In 1888, Garrett P. Serviss wrote in *Astronomy With An Opera-Glass* that the clusters are "marvelously beautiful objects in the sky — a double swarm of stars." Amedée Guillemin, in his 19th-century work *The Heavens*, stated, "The cluster in Perseus is at once a striking example, and one of the most glorious objects in the heavens. ... If a six-inch or a larger aperture can be used, he [the observer] will never forget the glorious picture unfolded before him." Herbert A. Howe, in the 1896 *A Study of the Sky*, added that the Double Cluster "is pretty in an opera-glass and fine in a small telescope. Here hundreds of suns are bunched together. This cluster is, for small telescopes, the finest visible in the United States."

Observe the Hero

You'll need optical aid to split the Double Cluster into its two parts. You'll get the finest views using low powers that give wide fields of view. Autumn is also the best time to view the clusters. Good 7x35 binoculars show dozens of stars, and a rich-field telescope at 15x to 20x gives an even better view. Large telescopes with 20- to 30-inch mirrors can provide the feel of swimming through a sea of stars.

I have used many telescopes to observe the Double Cluster. My favorite is a 4¼-inch scope that provides extremely wide views. Through a slightly smaller telescope (my 3-inch refractor at 50x), the two clusters look like sugar crystals sprinkled onto black velvet.

With my 4¼-inch scope and a 16mm eyepiece (27x), the Double Cluster is easy to resolve into two distinct objects. NGC 869, also known as h Persei, is the richer and more luminous of the two clusters. Several bright stars near the cluster's center cause it to appear as if it's closer than its twin. NGC 884, also known as Chi (χ) Persei, doesn't appear as dense or as rich. A number of red stars stand out, which gives the cluster unique coloration. The slowly pulsating red variable RS Persei lies at the center of NGC 884. Watch for it to change from 8th to 10th magnitude over a period of approximately 225 days.

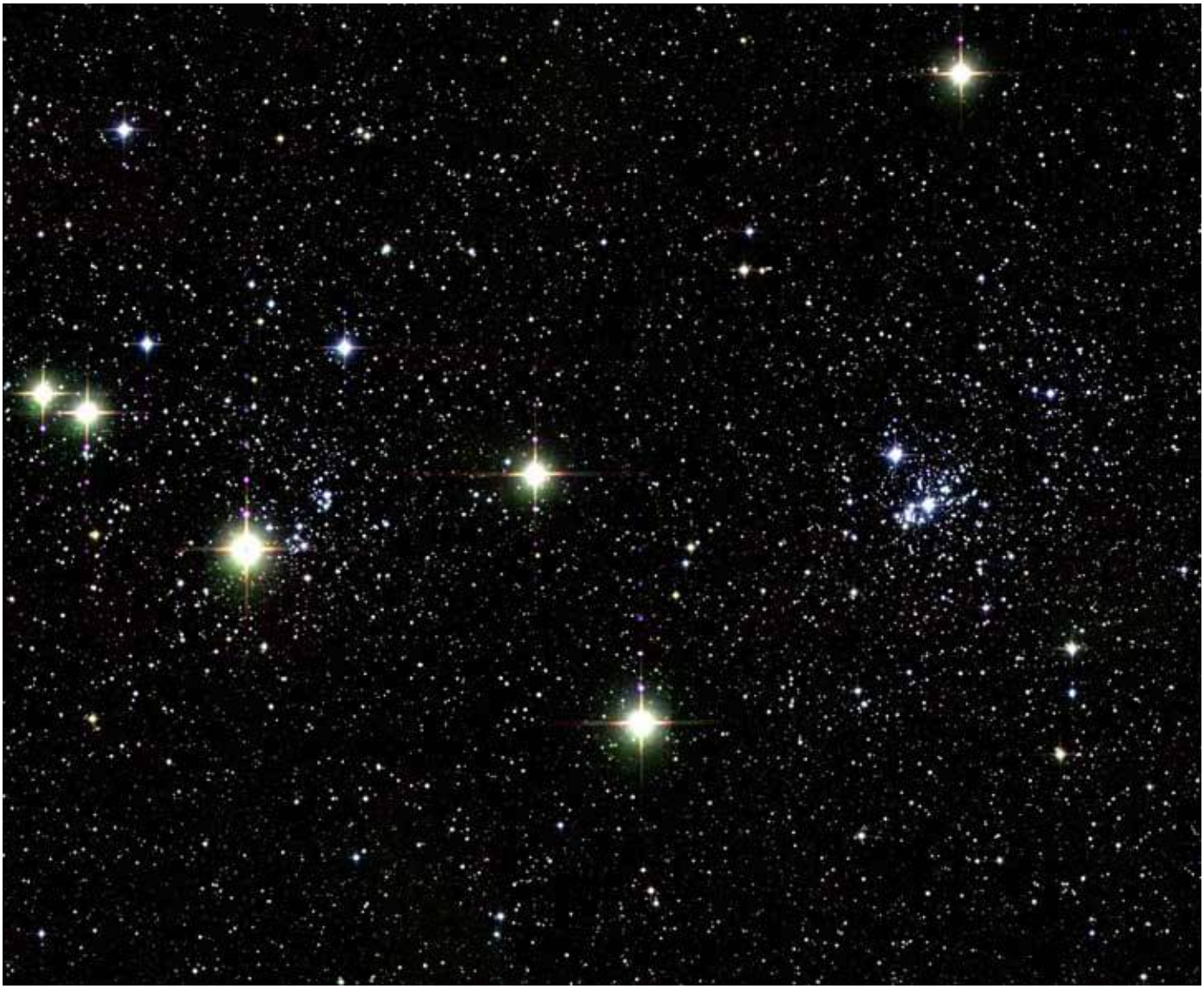
The Double Cluster at a glance

	NGC 869	NGC 884
Other names:	h Persei	Chi (χ) Persei
Constellation:	Perseus	Perseus
R.A.:	2h19m	2h23m
Dec.:	57°08'	57°09'
Size:	29'	29'
Magnitude:	5.3	6.1
Distance:	7,400 light-years	7,600 light-years

R.A.=Right ascension (2000.0); Dec.=Declination (2000.0)

How they fit in

The Milky Way is a large spiral galaxy containing more than 200 billion stars. An edge-on view shows a double "hub cap" shape. The galaxy's disk is 120,000 light-years wide, and our Sun about 26,000 light-years from the center. A halo of spherical globular clusters composed of tens of thousands of 10-billon-year-old stellar relics surrounds the disk. The galaxy's arms, on the other



An infrared view of the Double Cluster differs from a visible-light view. Redder stars, for example, appear brighter and bluer stars look fainter in this image. Atlas Image mosaic courtesy of 2MASS/UMass/IPAC-Caltech/NASA/NS/S. Van Dyk (IPAC)

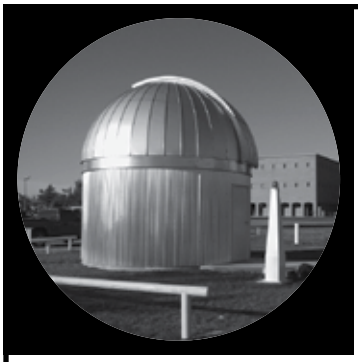
hand, contain gas and dust from which hot young stars form. These stars always hatch in large open clusters of hundreds or thousands of stars. NGC 869 and NGC 884 hold super-hot blue giants that consume their nuclear fuel at astoundingly fast rates.

Open clusters, such as those in Perseus, provide a powerful tool for measuring distance and age within our galaxy. A 2009 study of NGC 869 and NGC 884 determined that these two clusters are each about 14 million years old. Astronomers can determine the age of a star cluster by plotting its stars on the Hertzsprung-Russell diagram — a graph that compares luminosity to temperature. Most of the stars in an open cluster fall on the main sequence (meaning they, like the Sun, convert hydrogen to helium in their cores). However, some hot B-type stars have evolved past the main sequence. These stars use up their hydrogen fuel in only about 100 million years, thus giving away a cluster's approximate age.

Studies of the Milky Way's structure indicate that our galaxy has four spiral arms and a spur. Our Sun and planets reside in the Orion Spur. The Double Cluster sits in the adjacent Perseus Arm. Current measurements place NGC 869 and NGC 884 at 7,400 and 7,600 light-years away, respectively, but it appears this distance is shrinking: The two clusters are approaching the solar system at about 14 miles per second (22 kilometers per second). Astronomers determined this by looking at a shift in the cluster's emitted light. NGC 869 and NGC 884 show the light shifted toward the blue end, which indicates they're moving toward our region of space.

Because we have to look along the arm of the Milky Way to see the two clusters, we also have to look through the dust and gas that fill the galaxy's arms. Some observers have speculated on what we'd see without the intervening dust. Each of these clusters contains more than 300 blue-white supergiant stars. Although they're at a distance of some 7,400 light-years, the sight without dust would be awe-inspiring.

While we can't get rid of the intervening dust, we can still view beauty in the Double Cluster. So grab your telescope — any size will do — and turn it toward Perseus' sword to see two glittering star clusters.



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The Ash-Dome pictured is our 16'6" diameter unit. Housed is a 14-inch Schmidt-Cassegrain telescope equipped with a CCD camera and spectrograph. Students enrolled in astronomy are able to conduct research. The Astronomy Department encourages local students of all ages and astronomers in the community to collaborate with undergraduate students. The NOC Observatory has hosted over 800 visitors over this past academic year.

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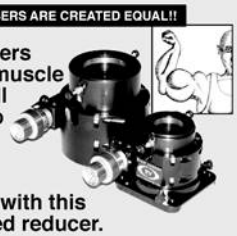

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Astroimager's delight: Canon's EOS 5D Mark II

Ease of use, tons of features, and a whopping 21 megapixels of resolution are all reasons to look at this camera. **by Mike Reynolds**

Low resolutions, slow responses, and high-priced gizmos — astroimaging has come a long way since its inception. The past 50 years have seen major advances in film chemistry, film sensitivity, new imaging techniques such as using cold cameras and hypersensitized films, and, of course, digital imaging.

My first digital single-lens reflex (DSLR) camera was Canon's EOS 10D, which featured a 6.3-megapixel chip. For my next camera, I moved up to Canon's EOS 20Da, which the company optimized for astronomical photography. This 8.2-megapixel camera integrated a special filter that increased transmission of the Hydrogen-alpha line, a wavelength many nebulae emit. The result was better images of red nebulae.

Mega-features

Enter the high-megapixel, full-frame DSLRs like Canon's EOS 5D Mark II. For the many amateur astronomers who have invested in the Canon line, this is a natural upgrade. This camera contains a 21.1-megapixel, full-frame complementary metal-oxide semiconductor (CMOS) chip that measures 35.9mm by 24mm. The sensor's size lets imagers capture a wider field of view than they could with previous smaller chips.

Canon's EOS 5D Mark II contains a 21.1-megapixel, full-frame complementary metal-oxide semiconductor (CMOS) sensor that captures celestial objects in high resolution. All camera images courtesy of Canon U.S.A.

The 5D Mark II offers ISO speeds from 100 to 6400 (expandable to a low ISO of 50 and a high of 25600). The camera also can capture high-definition video (1920x1080).

One feature that Canon touts is how rugged the EOS 5D Mark II is. I found out the hard way when the camera slid off my tripod and fell 6 feet onto a concrete floor. The only damage the EOS 5D suffered was some minor scuffs.

For this review, I primarily imaged through a 5-inch f/7.5 apochromatic refractor with a field flattener. The images were terrific. I compared them to some taken with the Canon 20Da. Even with the advantage the 20Da had because of its red-permeable filter, the 5D's images were of much higher quality.

One thing that amazed me was how fast the EOS 5D saves large images to its CompactFlash® (memory) card. With my old EOS 10D, waiting for the camera to save an image often meant missing other shots. For example, recently I wanted to rapidly image a series containing the Moon and the Pleiades (M45) open star cluster in close proximity. The EOS 5D allowed me to shoot multiple bracketed images quickly.

This camera has several other features I really like. One is its large (3.0-inch, 920,000 dot) LCD view screen. (The screen produces clear images, but I still carry a computer into the field to view my data.) The EOS 5D's controls and menu also are easy to use, whether in a regular or low-light situation.

Product specifications

Canon EOS 5D Mark II
Sensor: 21.1-megapixel CMOS chip
ISO range: 50–25600
Continuous shooting: 3.9 frames/second
Viewfinder: 3.0", 920,000 dot LCD monitor
Viewfinder coverage: 98 percent
Video capture: 1920x1080 resolution
Price: $2,099.99 (body only)

Mike Reynolds *is a contributing editor of* Astronomy *and Dean of Liberal Arts and Sciences at Florida State College at Jacksonville.*

The Lagoon and Trifid nebulae (M8 [bottom] and M20 [top]) plus emission nebula NGC 6559 shine along with thousands of Milky Way stars in Sagittarius. Imager Dean Salman took this 10-minute shot through the Canon EOS 5D Mark II set at ISO 800 attached to a 7.2-inch Takahashi Epsilon 180 Astrograph at f/2.8. He set the camera to "auto dark" and picked a single exposure to show what the Canon can reveal. Dean Salman

The EOS 5D lets you save images as JPG or RAW files, and you can set it to save more than one format per image taken. I shoot all of my astronomical images as RAW files, which generates the most data and doesn't compress the files. And here's a bonus: The EOS 5D performs an automatic sensor cleaning whenever you turn the camera on or off.

One accessory I recommend is Canon's TC-80N3 remote control. It allows me to set multiple images with specific exposure times and the time between each exposure. This feature will come in handy if your computer fails or if you want to image without a computer driving the system.

The only thing about the camera that I don't like is that it uses a different battery than previous Canon DSLRs. If the EOS 5D is your only camera, that's not a big deal. But it means I can't use my other batteries as spares. That said, the battery Canon developed for the EOS 5D is a higher-power (1800 milliamp-hour) upgrade, so you'll get more shots per battery charge than from earlier versions.

Go shoot the sky

I imaged a variety of sky objects both difficult and easy. One target I went after was a close approach of the Pleiades by the Moon. Part of the challenge in imaging this celestial pairing is not overexposing the lunar crescent and yet capturing the star cluster. I took a burst of short-exposure images at 1/125 and 1/250 second, and then I used image-processing software to stack them. I also imaged a variety of deep-sky objects such as the Rosette Nebula (NGC 2237–9).

All in all, I found the EOS 5D Mark II to excel mechanically, electronically, and optically. It's easy to use, produces outstanding non-astronomy photographs, and lets you enter the world of high-resolution astroimaging. The camera's features are refined and show that Canon continues to develop its excellent user interface. Also, the EOS 5D's price will decrease as new models appear. Indeed, this may be the camera that takes you into the high-resolution age.

Contact information

Canon, U.S.A.
One Canon Plaza
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[t] 800.652.2666
[w] www.canon.com

On the camera's back side, you'll find the 3.0" LCD viewfinder and all the controls that will allow you to navigate through the EOS 5D's imaging functions.

Find reviews of the Canon 10D and 20Da DSLRs at www.Astronomy.com/toc.

The Cosmic Grid

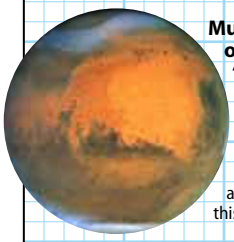
All things high, low, weird, and wonderful in astronomy and space science. **by Bill Andrews**

WEIRD

HOT

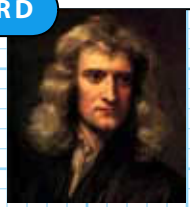
NOT

PREDICTABLE

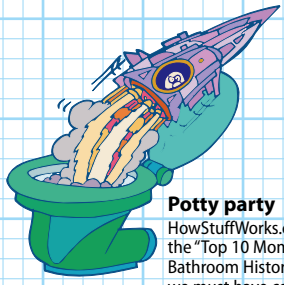


Musical mountains of Mars
"Total Recall: The Musical" becomes a YouTube sensation, as its audience can't get enough of "The Mountains of Mars." But are we only dreaming this song exists?

Holes all the way down
A newly published theory hypothesizes black holes contain other universes, and our universe may be in some larger universe's black hole — just in case your mind hasn't been blown in a while.

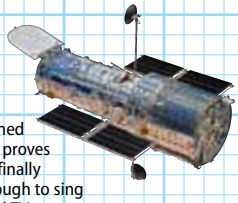


Small step for fruit
A piece of Sir Isaac Newton's apple tree — the one that allegedly inspired the theory of gravity — experienced weightlessness aboard *Atlantis*' May flight. How … ironic?



Potty party
HowStuffWorks.com publishes the "Top 10 Moments in Space Bathroom History." I feel like we must have covered at least half of them here on The Cosmic Grid by now.

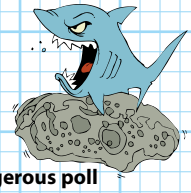
Gaming for science
Cynthia Breazeal and the Personal Robot Group of MIT release an online game named "Mars Escape," allowing you to combine your love of space, science, and video games all at once.



Late night with Hubble
A segment on *Late Night with Jimmy Fallon* named "Hubble Gotchu" proves that Hubble has finally become cool enough to sing about on national TV.

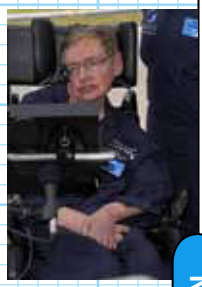
Time for reflection
Experiments suggest that dark matter may actually be "mirror matter," lightly interacting versions of every particle in the standard model of physics. Comic books suggest that "The Mirror Matter" might be a great name for a story involving astrophysicists.

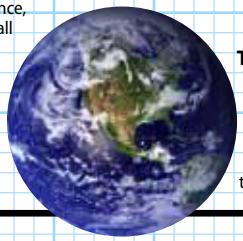
Science imitates art
NASA Science News publishes a story titled, "How Capt. Kirk Changed the World." Presumably, they mean besides the cologne at right.



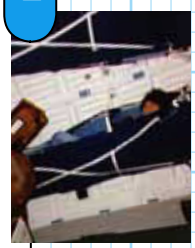
Dangerous poll
NOVA researcher Kate Becker posts a poll asking, "Which is more dangerous: A shark or an asteroid?" It goes without saying that sharks riding asteroids are unstoppable.

UpSETI
Astrophysicist Stephen Hawking offends SETI scientists and exobiologists when he says during a Discovery Channel show that it might be "too risky" to try to communicate with extraterrestrials.





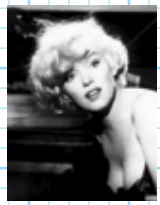
True blue
NASA releases the most true-color images of Earth ever; still looks blue and green to me, though.



Space sleep
National Space Biomedical Research Institute scientists develop mathematical software to help astronauts know the best time to go to sleep, because apparently astronauts just never get tired.

Artistic images
New Scientist interviews an art professor about the artistic choices within Hubble's images. Indeed: The raw data does have a certain pointillist structure …

Right priorities
Stephen Hawking writes in the *Daily Mail*, "If I had a time machine, I'd visit Marilyn Monroe in her prime or drop in on Galileo." Genius astrophysicists: They're just like us!



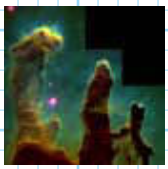
To boldly smell
Online stores begin selling Tiberius, "a casual yet commanding cologne" named after Captain James (Tiberius) Kirk. For some reason.

Space scholarships
The Astronaut Scholarship Foundation auctions off astronaut memorabilia for scholarships. Finally, NASA sells off supplies for the right reasons!

Alien etiquette
A poster titled "Let's say you're the first human ever to make alien contact" makes waves on the Internet. If you're a fan of this magazine, you probably have a greater-than-average chance of putting such knowledge to good use, so read up.

Private docking maneuvers
NASA's YouTube video "Shuttle's Toilet Requires Special Training" quickly becomes one of their most popular videos and allows us to check off another top 10 space bathroom moment.

Bright lights, big taxes
The Chinese metropolis of Guangzhou plans to impose special taxes on creators of light pollution to prevent health problems and improve stars' visibility. New York's Times Square responds, "Stars?"



Hubble's big two-oh
Hubble turns 20, and people everywhere think fondly of their favorite Hubble photo — because who doesn't have one?

Futurish-tic adventures
The world's first laser turns 50. Man, even futuristic technology is getting old.

PHOTOGRAPHS: Jim Bell (Cornell) et al., Hubble Heritage Team (AURA/STScI/NASA) (Musical mountains of Mars); NASA/CXC/M. Weiss (Holes all the way down); Sonia Chernova (Gaming for science); NASA (Late night with Hubble); NASA (True blue); Sir Godfrey Kneller (Small step for fruit); © 2010 Jupiterimages Corporation (Potty party); © 2010 Jupiterimages Corporation (Dangerous poll); NASA (UpSETI); *Some Like It Hot* trailer (Right priorities); Photos.com (To boldly smell); NASA (Private docking maneuvers); UpstateNYer (http://en.wikipedia.org/wiki/User:UpstateNYer) (Bright lights, big taxes); © 2010 Jupiterimages Corporation (Futurish-tic adventures); NASA (Space sleep); Georges Seurat (Artistic images); NASA (Space scholarships); Ian Markson / ian@union.io (Alien etiquette); NASA/ESA/STScI/J. Hester and P. Scowen (Arizona State University) (Hubble's big two-oh)

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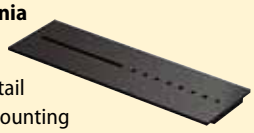

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INDEX of ADVERTISERS

Adorama 27
Ash Manufacturing 61
Astro Domes 66
Astro Haven 66
Astro-Physics 66
Astrodon 66
Astronomics 7
Astronomy.com 65
Astronomy magazine 27
Astronomy Technologies 66
Birder's World magazine 19
Celestron 73
Denkmeier Optical 66
Equatorial Platforms 66
Explore Scientific 13
Fishcamp Engineering 67
ISTAR Optical 66
Jim's Mobile, Inc. 61
Khan Scope Centre 67
Let's Talk Stars 66
Lightholder Optics 67
Lumicon 67
Meade Instruments Corporation 74
Observatory Inc., The 61
Oceanside Photo & Telescope 25
Optic Wave Laboratories 66
Optical Mechanics, Inc. 66
Orion Telescopes & Binoculars 4
Pro-Com Electronics 66
Rainbow Symphony 66
Santa Barbara Instrument Group 2
Scope Buggy 61
ScopeStuff 66
SCS Astro 66
SmartAstronomy.com 67
Software Bisque, Inc. 23
Starlight Instruments, LLC 67
Stellarvue 67
Teaching Company, The 9
Technical Innovations 27
Tele Vue Optics, Inc. 3
TravelQuest International 67
Vixen Optics 24
Woodland Hills Cameras and Telescopes 61
www.bigbinoculars.com 67

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Imaging the Cosmos

by Tony Hallas

Signal-to-noise ratio

Top-notch processing involves accentuating the positive and minimizing the negative.

In my initial column last month, I talked about why I prefer charge-coupled device (CCD) cameras over hand-held digital ones. This month, I continue my discussion of CCD imaging by examining something called the "signal-to-noise ratio."

Astroimagers use the term "signal" to denote the data — the good stuff that we want in our images. Unfortunately, mixed in with the signal is noise, and it's always present. Noise can come from many sources. Two are your CCD camera and your computer. Luckily, most noise is typically random. This means the more frames you have to average together, the more the random data smooths out.

Combining multiple images is highly superior to using just one image.

As it turns out, combining multiple images is highly superior to using just one image. There is a simple formula for this action: The gain in the signal-to-noise ratio is equal to the square root of the number of frames averaged. That means combining four frames will double your signal-to-noise ratio (2 is the square root of 4), and using nine frames will triple your signal-to-noise ratio (3 is the square root of 9).

As you go out further and further, you'll see that to get a fivefold increase, you have to shoot a whopping 25 frames, and a sixfold gain requires 36 frames! Obviously, there's a diminishing rate of return for the number of frames used. Also, when you use dozens of frames, other noise begins to enter the picture. I typically try to use nine frames for each of my images. I usually will shoot more than nine frames, but I only process the best nine.

Everything I have noted so far can be lumped into the process called "reduction of data." It's the step prior to image processing. You have your collected data, and you want to make it as good as it can be before you actually process it into an image.

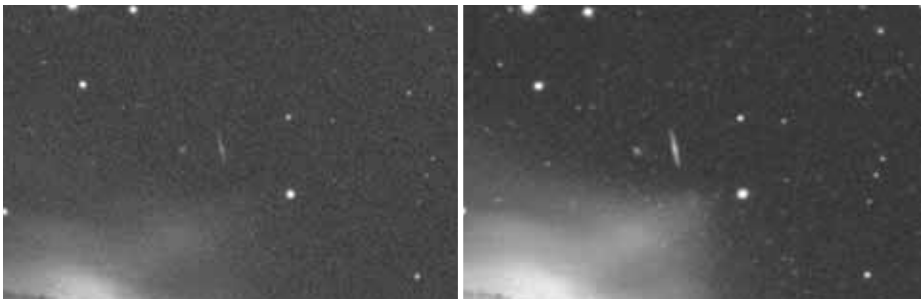
Dark current (top), which Hallas described in last month's column, introduces electronic noise into astroimages taken with CCD cameras. Luckily, it's easy to remove with software. The result (bottom) speaks for itself. All images: Tony Hallas

All CCD cameras need to have the data reduced in some manner before an imager can process it. It is vital to master this step so that your data is the best possible. You don't want to hear, "Garbage in, garbage out." Instead, you want well-reduced data that, when taken into Adobe *Photoshop*®, will come alive with amazing detail.

I hope these first two columns have taken some of the mystery out of the CCD camera. You'll learn more if you are fortunate enough to have an active astronomy club nearby. There always seems to be imagers among the members, and I highly recommend spending some time with them. They will have hands-on suggestions about good imaging equipment — not just cameras, but also telescopes and mounts — as well as firsthand comments about what software they like.

It's always a good time to talk about astroimaging, but now is especially so. Prices for entry-level CCD cameras have dropped, and you don't need a high-end camera to produce amazing images.

In my next installment, I will explore how to use *Photoshop* to stretch the data you collect, and I'll explain why I use some of the techniques I do.



Combining images produces a superior signal-to-noise ratio. Compare the single 450-second image on the left to the one on the right, which resulted from combining (stacking) eight 450-second images.

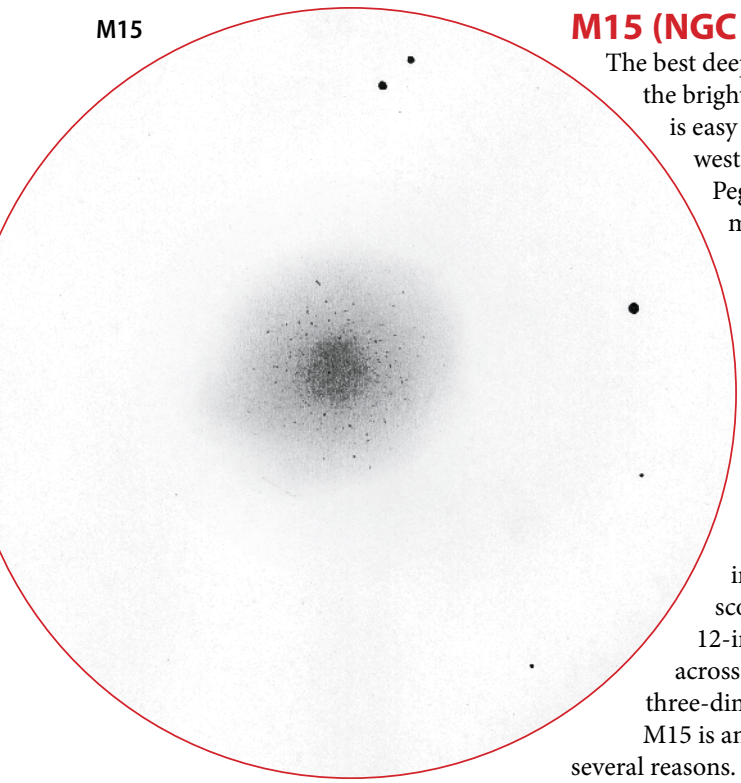
Browse the "Imaging the Cosmos" archive at www.Astronomy.com/Hallas.

Deep-sky Showcase

Astronomy's *editor sketches two of his favorite objects.* **by David J. Eicher**

M15 and NGC 7331

M15



M15 sketched by David J. Eicher using an 8-inch f/10 SCT at 50x.

M15 (NGC 7078)

The best deep-sky object in Pegasus is the bright globular cluster M15. It is easy to find, lying 4° northwest of Enif (Epsilon [ε] Pegasi). Appearing as a magnitude 6.2 fuzzy "star" through finder scopes or binoculars, M15 has an appearance that changes with a 4-inch or 6-inch scope. At low power, the cluster's disk appears evenly illuminated, while high powers (100x or more) resolve the cluster's edges into tiny stars. Larger telescopes do even better: A 12-inch scope resolves stars across M15's face to create a three-dimensional effect.

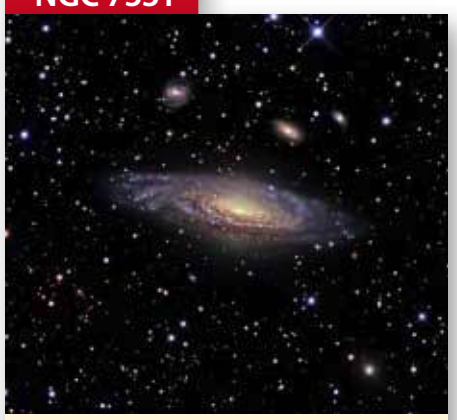
M15 is an unusual globular for several reasons. It is an intense X-ray source, leading astronomers to believe it may harbor a central black hole. It contains a huge number of variable stars, 112 in all, most of which are faint RR Lyrae-type stars. Curiously, M15 also contains a planetary nebula, Pease 1, one of only four known within globular clusters. The nebula measures only 3" across and glows dimly at magnitude 14.9; it is difficult to pick out with backyard telescopes.

M15

Don Goldman

Designations: M15, NGC 7078
Position: 21h30m, 12°10' (2000.0)
Constellation: Pegasus
Magnitude: 6.2
Size: 18.0'
Distance: 33,000 light-years

NGC 7331



R. Jay GaBany

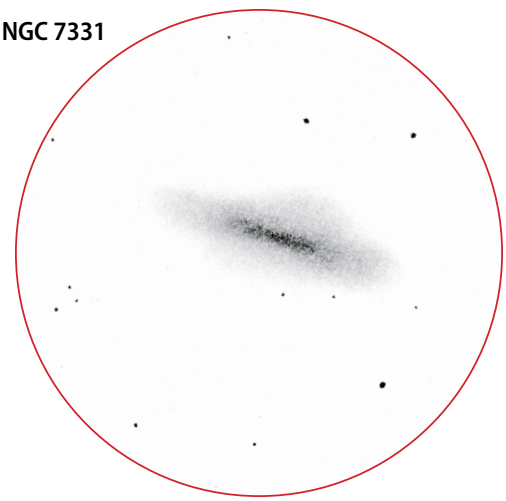
Designation: NGC 7331
Position: 22h37m, 34°25' (2000.0)
Constellation: Pegasus
Magnitude: 9.5
Size: 10.5' by 3.7'
Distance: 46 million light-years

NGC 7331

Pegasus contains a multitude of bright galaxies for small-telescope users. The finest is NGC 7331, a magnitude 9.5 Sb-type spiral that looks like a miniature version of M31, the Andromeda Galaxy. (Both M31 and NGC 7331 are similar types of objects, but they appear different because NGC 7331 is about 18 times more distant.) Lying 4.3° north and slightly west of the bright star Eta (η) Pegasi, NGC 7331 is visible through finder scopes under a dark, moonless sky.

A 3-inch telescope shows the galaxy as a small oval of gray-green light spanning about 5'. A 6-inch scope at high power reveals a bright, roundish nucleus enveloped in the oval disk. Under good conditions, a 10-inch scope shows a faint, uniformly lit halo of nebulosity — that feature is NGC 7331's spiral arms, which measure 10.5' by 3.7'.

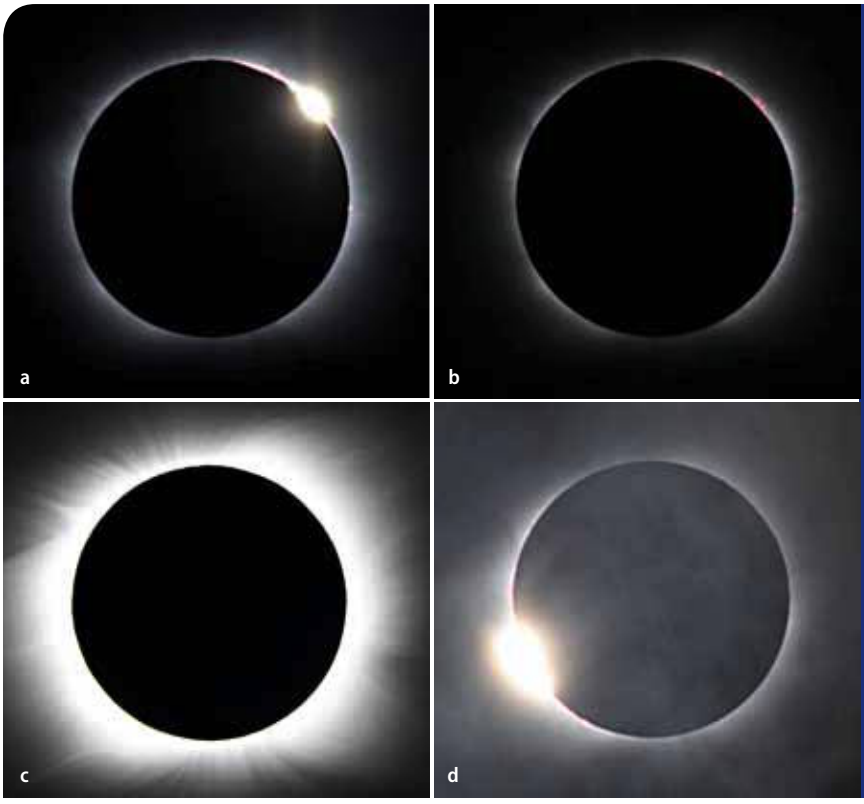
NGC 7331



NGC 7331 sketched by David J. Eicher using an 8-inch f/10 SCT at 50x.

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 34 years.*

reader gallery



Totality over the Pacific

On July 11, a tiny percentage of Earth's population stood under the Moon's shadow as our satellite passed in front of the Sun. *Astronomy* editors headed groups that traveled to the Tuamotu Archipelago (an atoll chain in French Polynesia) and Easter Island.

Forecasts gave travelers only a 50 percent chance of seeing the eclipse, but that day's weather favored both groups.

If you've got the eclipse bug, you'll have to wait until November 13, 2012, before the Moon once again eclipses the Sun. Maximum totality will last some 4 minutes and occur 1,300 miles east of Auckland, New Zealand.

Totality (3.2-inch Explore Scientific 80mm ED APO refractor at f/6.3, Canon EOS 5D Mark II DSLR, ISO 400 with exposures of $\frac{1}{2,000}$- [for a], $\frac{1}{8,000}$- [b], $\frac{1}{80}$- [c], and $\frac{1}{800}$-second [d], taken July 11, 2010, between 2:08:17 P.M. and 2:13:05 P.M. Easter Island local time) • Mike Reynolds, Jacksonville Beach, Florida

▶ **The diamond ring at third contact** appeared spectacular through thin clouds from aboard the *Aranui 3*, which cruised the Tuamotu Archipelago on eclipse day. (Nikon D-300 DSLR, 70-200mm f/2.8 lens set at 200mm and f/8, ISO 400, $\frac{1}{160}$-second exposure, taken July 11, 2010, at 8:42:16 A.M. local time) • Les and Mary Anderson, San Diego, California

Elliptical galaxy M105 (right of center) in Leo is a member of the Leo I group of galaxies. Another member is elliptical galaxy NGC 3384 (upper left), but not the more distant spiral NGC 3389. (12-inch Newtonian reflector at f/3.68, SBIG ST-2000XM CCD camera, LRGB image with exposures of 300, 80, 80, and 64 minutes, respectively) • Bernard Hubl, Nussbach, Austria

The Spider Galaxy (UGC 5829) is a gas-rich irregular dwarf galaxy in Leo Minor with low surface brightness. This seldom-imaged deep-sky object lies roughly 26 million light-years away. (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG STL-6303E CCD camera, LRGB image with exposures of 18, 8.5, 8.5, and 8.5 hours, respectively) • Mark Manner, Spot, Tennessee

▶ **On Easter Island,** one of the 887 Moai (stone sculptures) at the Tahai ahu (stone platform) site gave mute testimony to the total eclipse occurring overhead. (Nikon D-90 DSLR, Nikon AF-S Nikkor DX 18-105mm lens set at 38mm and f/4.5, ISO 1000, 1/8-second exposure taken July 11, 2010, at 2:09:17 P.M. Easter Island local time) • George Willis, Los Angeles, California

V1331 Cygni (top center) is a peculiar star surrounded by an elliptical envelope. The dark nebulosity below it, which astronomers refer to as LDN 981, may be the star's parent cloud. (24-inch RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG STL-11000 CCD camera, RGB image with exposures of 50, 30, and 50 minutes, respectively) • Adam Block, Mount Lemmon SkyCenter, University of Arizona

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.

Open cluster M23 in Sagittarius is one of Charles Messier's least-observed objects. That's a shame because it's gorgeous. To locate this fine sight, point your telescope 4.4° west-northwest of the magnitude 3.8 star Mu (μ) Sagittarii, toward the thickest part of the Milky Way. M23 shines brightly at magnitude 5.5 and measures 27' across, a size nearly equal to the Full Moon. (6.2-inch Astro-Physics 155 EDF apochromatic refractor at f/5.4, FLI KAF-16803 Proline CCD camera, LRGB image with exposures of 110, 80, 80, and 140 minutes respectively) • Thomas Davis, Inkom, Idaho

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